ANNUAL REPORT

OF THE

DIRECTOR
BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1920

(Miscellaneous Publications—No. 44)

WASHINGTON
GOVERNMENT PRINTING OFFICE
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Washington, D. C.

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and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

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REPORT

OF THE

DIRECTOR, BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 1, 1920.

SIR: There is submitted herewith a report of the work of the Bureau of Standards for the fiscal year ended June 30, 1920.

I. FUNCTIONS, ORGANIZATION, AND LOCATION.

Before describing in detail the various scientific and technical problems in which the Bureau of Standards is engaged, the following brief statement as to its functions and organization may be helpful to those unfamiliar with the subject of standardization in its broad and modern sense.

The standards with which the Bureau is authorized to deal may be conveniently classed as follows: Standards of measurement, standard values of constants, standards of quality, standards of mechanical performance, and standards of practice.

1. DEFINITION OF STANDARDS.

Standards of Measurement.

A standard of length may be taken as an example of a standard of measurement. It must be a length which is unchanging, reproducible, and capable of being compared with the working standards used in the most precise scientific work or with those used in commerce and industry. In order to carry out such comparisons, working standards must be prepared which are subdivisions and multiples of the fundamental standard, and this process of subdividing and multiplying the standard involves difficulties as great as those met with in the preparation of the fundamental standard itself.

The construction of a set of standard weights from a single unit is also an illustration; a whole set of standard weights must be prepared before the standard weight of the Government can become available to the public. Before these working standards, made up of subdivisions and multiples of the fundamental standard, can be prepared, questions as to the methods of comparison arise, which again involve the solution of difficult scientific problems in connection with the balance or the methods used. These balances range from that

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FUNCTIONS

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STANDARDS	PURPOSE
1 **STANDARDS OF MEASUREMENT** Reference and working standards for measurements of all kinds, including fundamental and derived STANDARDS OF MEASUREMENT for expressing the quantitative aspects of space, time, matter, energy, motion and of their interrelations. By definition, specification, or material standard, covering, for example, length, area, and volume; mass, weight, density, and pressure; heat, light, electricity, and radioactivity, including quantity, flux, intensity, density, etc.	To aid ACCURACY IN INDUSTRY through uniform and correct measures; To ASSIST COMMERCE IN SIZE STANDARDIZATION of containers and products; To PROMOTE JUSTICE IN DAILY TRADE through systematic inspection and regulation; To facilitate PRECISION IN SCIENCE and TECHNOLOGIC RESEARCH through calibration of units, measures, and instruments involved.
2 **STANDARD CONSTANTS** Natural standards or the measured numerical data as to materials and energy, known as physical or STANDARD CONSTANTS, i. e., the fixed points or quantities which underlie scientific research and industrial processes when scientifically organized. Mechanical equivalent of heat, light, and electricity and of gravitation; specific densities; viscosities; melting and boiling points; heat capacity; heats of combustion; velocity of propagation of light; conductivities of materials to heat and light; electrochemical and atomic weights and many similar magnitudes determined experimentally with maximum precision and referred to fundamental standards of measure.	To SERVE as an EXACT BASIS for scientific study, experiment, computation, and design; To FURNISH an EFFICIENT CONTROL for industrial processes in securing reproducible and uniformly high quality in output; To SECURE UNIFORMITY OF PRACTICE in graduating measuring instruments, compiling tables, in standards of quality and performance, and wherever uniformity is desirable; To AID LABORATORY RESEARCH BY REDUCING ERRORS and uncertainty caused by use of data of doubtful accuracy.
3 **STANDARDS OF QUALITY** Specifications for material (by description, sample, or both), known as STANDARDS OF QUALITY, fixing in measurable terms a property or group of properties which determine the quality. The numerical magnitude of each constituent property pertinent to the quality involved, and specific magnitude in units of measure of such significant factors as uniformity, composition, form, structure, and others.	To secure HIGH UTILITY in the PRODUCTS of industry by setting an attainable standard of quality; To furnish a SCIENTIFIC BASIS for FAIR DEALING to avoid disputes or settle differences; To PROMOTE TRUTHFUL BRANDING and ADVERTISING by suitable standards and methods of test; To PROMOTE PRECISION and AVOID WASTE in science and industry by affording quality standards by which materials may be made, sold, and tested.
4 **STANDARDS OF PERFORMANCE** Specification of operative efficiency or action, for machines and devices, STANDARDS OF PERFORMANCE, specifying the factors involved in terms susceptible of measurement. Numerical statement of speed, uniformity, output, economy, durability, and other factors which together define the net efficiency of an appliance or machine.	To CLARIFY THE UNDERSTANDING between maker, seller, buyer, and user, as to operative efficiency of appliances and machines; To make EXACT KNOWLEDGE THE BASIS OF the buyer's choice; To STIMULATE AND MEASURE MECHANICAL PROGRESS.
5 **STANDARDS OF PRACTICE** Codes and regulations impartially analyzed and formulated after study and experiment into STANDARDS OF PRACTICE for technical regulation of construction, installation, operation, and based upon standards of measurement, quality, and performance. Collation of standard data, numerical magnitudes, and ranges of the pertinent factors defining quality, safety, economy, convenience, and efficiency.	To FURNISH for each utility a single IMPERSONAL STANDARD of practice as a BASIS FOR AGREEMENT of all interests clearly defined in measurable terms; To INSURE EFFECTIVE DESIGN and INSTALLATION of utilities of all kinds; To PROMOTE SAFETY, EFFICIENCY, and CONVENIENCE in the maintenance and OPERATION of such utilities; To SECURE UNIFORMITY OF PRACTICE where such is practicable, and EFFECTIVE ALTERNATES in other cases.

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capable of measuring the thousandth part of a milligram to the large testing machine capable of measuring a load of thousands of tons. The complete range must be covered which involves not only a large number of working standards, all of which must agree with the fundamental standard, but apparatus suitable for the comparison of these standards with all of the lengths or weights found in practice.

These steps and equipment are absolutely essential in order to secure uniform measurements of length or weight throughout the country, and they have their counterpart in every quantity that has to be measured, whether it be length, weight, temperature, heat, light, or the various electrical measurements or other standards of measurement. These standards in one form or another are involved in practically every scientific investigation, industrial process, engineering structure, or commercial transaction.

Physical Constants (Standard Values).

There are many fixed relations between physical quantities, the values of which it is extremely important to know. These values are usually termed "physical constants," and are used in every branch of scientific work or industry. The amount of heat required to change a pound of water into steam under normal conditions and the relation between heat and mechanical energy are two important physical constants; their values are used in practically every computation in connection with the designing of steam engines and boilers, the tests of their efficiencies, or the measurement of their output. The amount of heat required to turn liquid ammonia into vapor or the amount of heat required to melt a pound of ice are constants equally important in the refrigerating industries. The value of the relation between electrical and mechanical energy is involved in many commercial transactions concerned in electricity.

Accurate and authoritative values of these constants are just as essential as in the case of standards of measurement. Many of those now in use are old and obsolete and need redetermination by means of the best modern facilities for physical measurement. Their determination involves the most difficult and precise work in all branches of physics and chemistry—a fact not generally known by those not engaged in the scientific or technical work where these constants are used.

Standards of Quality.

A standard of quality for a given material may sometimes take the form of a sample of that material with which other materials of the same kind can be compared, but this is generally a makeshift of the poorest sort. It is only resorted to in the absence of definite and reliable specifications in terms of measurable properties; that is to say, a standard of quality of a material usually takes the form of a specification or definition of its properties, involving, of course, the measurement of those properties by means of the usual standards of measurement. A certain kind of steel, a cement, a paint, an oil, a paper or a cloth is found by use to be good or poor for a definite purpose. The questions then arise: Why is it good or poor? What are the physical or chemical properties or the particular combination of elements which make it of good or poor quality? How are its

Work of the Bureau in an Advisory Capacity.

The Bureau serves in an advisory capacity for those officials of the States and municipalities charged with the administration of the laws governing weights and measures. Likewise its advice is freely given concerning the use of exact standards in all lines of commercial activity. This information is of the first importance to many of our industries. As an example it may be stated that the success or failure of an industrial enterprise may depend upon the securing of correct information concerning the control of temperature, advice which can be secured only from such an institution as the Bureau.

A great many inquiries are also received concerning the use of the various materials of construction, and the Bureau has frequently assisted in the preparation of specifications on which to base the purchase of materials of this kind.

Many questions of disagreement between the public and utility companies as to matters involving the use of standards are referred to the Bureau for advice or adjustment, often avoiding unfair and inconsistent regulations, as well as long-drawn-out and expensive litigation. There is a great need on the part of the public for unbiased and reliable information pertaining to the standards entering into the regulation and sale of the services of public utilities. As far as possible, such information is given in the form of publications upon definite subjects.

In the formulation of safety codes, designed to govern electrical and other construction, the Bureau has taken an active part, particularly in the collecting and study of data, upon the correct interpretation of which the success of such regulations must always depend.

3. RELATION OF THE BUREAU'S WORK TO THE INDUSTRIES.

Assistance in Establishing Exact Standards of Measurement Needed in Industries.

It must not be inferred from the above that the Bureau's activities are devoted principally to the interests of the user or consumer. The fundamental facts regarding standards of measurement, quality, or performance are the very things which most deeply concern manufacturers; they are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output. It may be said that the Bureau occupies somewhat the same position with respect to the manufacturing interests of this country that the bureaus of the Department of Agriculture do to the agricultural interests. Many industries are just beginning to realize the importance of precise methods of measurement and scientific investigation which, in practically every case, involve some kind of measurement.

It is upon quality as well as upon price that competition must finally depend, whether in domestic or foreign commerce. The use of exact methods and scientific results is the greatest factor in the improvement of quality, efficiency, or the development of new industries. The educational value of the Bureau's work in this respect is almost entirely unknown to the general public, and yet the Bureau receives hundreds of letters, as well as many personal visits from

manufacturers, seeking information as to standards of measurement, how to use them, how to measure the properties of materials, or as to the fundamental, physical, and chemical principles involved; also, what is of even greater importance, how to initiate and carry out scientific investigations and tests on their own account in their particular fields of work.

The importance of maintaining scientific institutions having to do with standardization and the application of precise measurements to the industries has been recognized by all the leading countries of the world. Great Britain maintains the Standards Department of the Board of Trade, which is in charge of the standards and inspection service of the trade weights and measure; also the National Physical Laboratory, whose functions include matters pertaining to scientific and technical standards, physical constants, and to some extent the properties of materials. The Laboratoire d'Essais of France, while not as extensive as the English institution, is charged with similar duties. Germany maintains three such institutions—the Normal-Eichungs Kommission, equipped with the buildings, personnel, and apparatus necessary in standardizing and controlling the weights and measures of trade; the Physikalisch-Technische Reichsanstalt, covering testing and investigations in connection with scientific and technical standards other than weights and measures; and the Materialprüfungsamt of the Prussian Government, a large institution devoted to the investigating and testing of structural, engineering, and other materials.

It is generally recognized that these institutions have been exceedingly important factors in the industrial progress of these countries.

The Collection of Fundamental Data for the Industries.

During the past year the Bureau's relations to the industries have been closer than ever before. Many firms have entered upon the manufacture of goods formerly produced only in foreign countries, and in this work (much of which is of a pioneer nature in the United States) hundreds of important questions concerning methods of measurement and the properties of materials have required solution. In numerous cases the Bureau has helped to solve these problems through special investigations conducted in its laboratories, the results of which have been freely given to the industries, with the result that improved processes have been adopted, resulting in a more satisfactory product and more economical method of production.

Training of Experts in Various Industrial Fields.

Through the increased activities of nearly all the industries of the country and the demand for trained investigators, the Bureau's scientific staff has been largely depleted, and it will be a matter of some time before it can be brought back to the plane of high efficiency which it has previously maintained. It is to be regretted that during the year covered by this report conditions were such that the salaries paid the Bureau's experts in all lines of scientific work are still wholly inadequate, and it is assumed that during the present year steps will be taken to place the compensation of scientific and

technical men in the Government service on a scale more commensurate with that paid by scientific institutions and industrial laboratories. Even then the industries should cooperate in every way possible to maintain the Bureau's staff intact and of the best material. Many instances could be given where the industries have taken experts with little warning and with no apparent consideration as to the consequences. The training of men for research is one of the most important ways in which the Bureau can aid the industries; but to do this it is necessary to maintain its own staff in the highest degree of efficiency.

4. RELATION OF THE BUREAU'S WORK TO THE GOVERNMENT.

Comparison of Standards of Other Government Departments with Those of the Bureau.

The use of exact standards enters into every branch of the Government service, as it does into every industry and into the everyday life of all persons. It was in the Government service, however, that the need for exact standards was first appreciated. The work done for the Government is in nowise different from that carried on for individuals and involves the same problems.

Many bureaus of the Government service are charged with the administration of laws and the establishment of regulations, the intelligent application of which depends very largely on the use of exact standards. This is true to a greater extent than is generally supposed. The Bureau of Standards has cooperated freely with these branches of the Government, and the service rendered has involved every department of physics and chemistry covered by the Bureau's activities. The neglect of such matters in the past has been a frequent source of misunderstanding and litigation between the Government service and the public. Conspicuous examples of bureaus to which assistance has been given are the Customs and Internal-Revenue Services, Steamboat-Inspection and Coast Guard Services, and the Bureau of Navigation of the Department of Commerce, as well as all bureaus of the War and Navy Departments engaged in construction or development work.

Performance of Tests and Investigations and the Collection of Scientific Data of a Fundamental Nature.

The engineering and building construction in progress at all times by the Government is exceedingly great, both in variety and magnitude; in all of it a knowledge of the materials employed is of fundamental importance from the standpoints of economy, efficiency, and safety. The work of investigating the properties of structural materials was taken up and is carried on primarily for the purpose of securing the information needed by the Government service in its structural work. This information is necessary to the public in construction work, and every effort is made by the Bureau to render its findings available to the public generally. The demands for information of this sort have come from practically all Government bureaus and establishments, but especially in connection with the structural work carried on by the Office of the Supervising Archi-

tect, the engineering branches of the Army, the Bureau of Construction and Repair of the Navy, the Panama Canal, and the Reclamation Service.

Advisory and Consulting Capacity.

One of the most important services which the Bureau has been able to render to other departments of the Government, both civil and military, has been of an advisory and consulting nature in matters pertaining to the scientific work in which these departments are interested. Too great emphasis can not be placed on the importance of this phase of the Bureau's work. Its maintenance would be warranted for this reason alone, even though its usefulness in this field is but a small portion of the total service which it has rendered other branches of the Government.

The Bureau's laboratories have been open and its experts available at all times to every department of the Government, and in many cases substantial help has been rendered to the military and civil departments through the familiarity of the Bureau with certain kinds of work, and its ability to quickly decide whether the particular methods, materials, or devices were suitable for the service in question.

The Bureau as a Testing Laboratory and Its Work in the Preparation of Specifications on Which to Base the Purchase of Materials.

The Bureau of Standards serves as a testing bureau for the various departments of the Government when called upon; and, as such, is assisting to place Govrnment purchases upon an economical and businesslike basis. The example of the Government in such matters has a far greater influence upon the public than is generally supposed. The Government can do no greater service to the country than to place its own purchases upon a basis which may be taken as a standard by the public at large. This work involves the specification of a wide range of structural and miscellaneous materials and their testing, when delivered, to ascertain whether or not they comply with the specifications. This is especially important, since such materials are purchased by means of competitive bids, a method resulting in much fraud and injustice unless suitable standards are established and successful bidders held absolutely to this standard in making deliveries. Furthermore, most purchasing officers are realizing the great importance of having such testing done by a disinterested institution equipped with the scientific and other facilities for performing the service in a manner that is fair to both parties concerned in the purchases.

Among the Government bureaus and establishments which have utilized the Bureau of Standards as a testing institution in connection with the purchase of supplies, may be mentioned the Government Printing Office, in connection with the purchase of paper, inks, and printing supplies, and the Post Office Department, in connection with the purchase of paper, twine, textiles, etc. A wide range of materials has been tested for the Quartermaster Corps of the Army, the Bureau of Supplies and Accounts of the Navy, and the Panama Canal. The General Supply Committee has called upon the Bureau

for assistance in the specification of all sorts of supplies and equipment, as well as the testing of samples submitted by bidders of the supplies bid upon. Practically every branch of the Government service, including the District of Columbia, utilizes the Bureau of Standards as a testing bureau. Here, again, as in other fields of the Bureau's activities, it gains much useful knowledge, which is given to the public in the form of suitable publications.

5. ORGANIZATION.

The organization of the Bureau's scientific and technical staff is based upon the nature of the expert service involved rather than upon the classes of standards. For example, the Division of Weights and Measures has to do with all matters pertaining to standards of length, mass (weight, as it is commonly termed), time, density, and similar questions, whether they arise in connection with the precision standards used in scientific investigation, the master standards of manufacturers, or the ordinary weights and measures of trade. A standard of quality or performance where any of the above measurements form the fundamental and most important factor would be referred to this division.

The Division of Heat and Thermometry has to do with heat standards, the testing of heat-measuring apparatus, the determination of heat constants, of which there are many, and all investigations pertaining to quality or performance where heat measurement is the essential and predominating factor.

Similarly, the Electrical Division is concerned with all the electrical problems that may be taken up at the Bureau, whether in connection with the various electrical standards of measurement, electrical constants, the electrical properties of materials, or the performance of electrical equipment.

Questions in optics enter into standards of all kinds to a greater extent than has been supposed; hence, there is an Optical Division provided, with experts in spectroscopy, polarimetry (used in sugar analysis), color measurement, the principles of optical instruments, and the measurement of the optical properties of materials.

Practically all investigations concerning the various classes of standards involve chemistry in one form or another. There are also many chemical standards and questions which arise in connection with chemical work generally, especially in the industries; hence, there is a Chemical Division, cooperating with every other division of the Bureau, as well as taking care of the questions of a purely chemical nature that come to the Bureau and which fall within its functions.

In the case of the more important technical fields, divisions have been formed dealing more specifically with large and important classes of materials, but many of the purely scientific questions involved would be handled by one of the above-mentioned scientific divisions or jointly with it. The work of the technical divisions is just as scientific in character, but deals more specifically with manufactured products.

The work of the Structural Engineering and Miscellaneous Materials Division includes the investigation, testing, and preparation of

specifications for these materials, such as the metals and their alloys, stone, cement, concrete, lime, the clay products, paints, oils, paper, textiles, rubber, and other miscellaneous materials.

The Division of Engineering Physics makes investigations and tests regarding the performance and efficiency of instruments, devices, and machinery. This work includes the testing of water and other meters, aeronautic instruments, etc., as well as investigations in aerodynamic physics and the study of sound.

Questions pertaining to the manufacture, specifications, testing, and use of the metals and their alloys is so important that a separate division, known as the Metallurgical Division, is provided to deal with these problems.

The employees engaged in clerical work, purchasing, files, records, and accounting, as well as those of the library and information section, form the Office Division, while those employed in the operation of the mechanical plant, the various shops, and the care of the buildings and grounds make up the Engineering and Construction Division.

6. LOCATION.

The laboratories and offices of the Bureau of Standards are located on a tract of about 28 acres in the northwest section of Washington, on Pierce Mill Road, near Connecticut Avenue, and are reached by the Chevy Chase car line. They were placed outside of the business center of Washington in order to insure freedom from mechanical, electrical, and other disturbances common to the business and more thickly populated sections of a city. Furthermore, the area of ground necessary precluded a site nearer the city. It has been found by experience that the efficiency of the employees, especially those engaged in testing and scientific investigation, has been greatly increased by the location of the laboratories in a section free from the ordinary disturbances of metropolitan life.

II. SCIENTIFIC AND TECHNICAL DIVISIONS.

1. WEIGHTS AND MEASURES.

The division of weights and measures is concerned with measurements involving the fundamental units of length, mass, and time, and such derived or secondary units as area, volume, density, and pressure. The activities of the division also include preparation of specifications and tolerances for use in connection with standardization of weighing and measuring apparatus; cooperation with States in the preparation, enactment, and enforcement of weights and measures legislation; the design, improvement, and inspection of weights and measures apparatus, and the carrying out of researches designed to result in more accurate knoweldge of physical constants.

LENGTH.

Investigation of Apparatus and Standards.

Considerable headway was made during the past year in the general problem of the investigation of the Bureau's apparatus and standards in order to have them in first class condition. The necessity for this investigation arose from the urgency of the testing work for the military departments during the war. This work of readjustment and calibration was begun last year and noted in the report for 1919.

The precision comparator box has been put into working condition, some obvious defects remedied and plans made for needed supplementary equipment to use in determining the coefficient of expansion of a precision line standard as well as for other purposes.

Several minor changes were made in the equipment used for testing base-line tapes. Parts of improved equipment—cut-off cylinders—which were made a number of years ago, have been installed and have greatly improved the accuracy, speed and general efficiency of the work. Certain improvements mentioned in a later paragraph remain to be made.

The methods of calibrating the intervals of line standards were investigated and as a result some changes were made in the method employed by the Bureau. This has resulted in a very considerable saving of time and the liability for mistakes has been much lessened.

Investigations in Testing of Block Gauges.

Considerable time was spent during the last half of the year on the general subject of interference methods of testing gauge blocks. The general conclusions reached were (*a*) that the standards used in checking the blocks must be frequently intercompared; (*b*) that the character of the blocks of Johansson set 9 is not such as would warrant any conclusions of inaccuracies which might appear from the comparison of Hoke blocks with blocks of that set; (*c*) that, when the Bureau's line standards are more thoroughly recompared and calibrated, very good values may be given for precision blocks by comparison with line standards.

Investigation of Standards and Means of Comparison.

The most urgent need of the section is a very fundamental one. The work of putting the precision comparator into the best working condition should be completed, the temperature control installed, and the work of intercomparing the Bureau's standards in a thorough and systematic manner taken up. Among the specific details of apparatus and methods which require attention there may be mentioned:

(*a*) Microscope objectives of precision comparator.
(*b*) Illumination of microscope.
(*c*) Temperature control of comparator box.
(*d*) Temperature control of comparator room.

Design and Construction of Instruments.

Several instruments itemized below are rather urgently needed and the first two should be designed and constructed as soon as possible.

(*a*) Comparator for calibrating the intervals of a graduated line standard.

(*b*) A small, very simple comparator consisting of a bed, carriage, rack and pinion, and microscope holders for examining and calibrating sieves microscopically, for measuring intervals on small scales and other small apparatus. This sort of work is now done on the dividing engine.

(*c*) A projection apparatus, similar to the newly developed screw-thread projection apparatus, for testing seives, provided the feasibility of the scheme is demonstrated by actual use on a thread projection apparatus when one is available.

Graduation of Linear Scales.

Frequent calls are made on this section by other divisions of the Bureau and branches of the Government for the graduation of special scales. The accuracy and character of these graduations range from diamond-scratched lines spaced very accurately to deep cuts in brass of the type often done on a milling machine. The facilities for this kind of work are entirely inadequate and should be increased.

Routine Testing of Length Standards.

The following is a list of articles tested by the length section during the year:

Length standards (yard and meter bars)	9
Haemacytometers	573
Invar tapes	14
Steel tapes	182
Reinforced cloth tapes	115
Spring balances for tapes	4
Sieves	47
Pieces sieve cloth (16.7 square feet)	6
Level rods	5
Polariscope tubes	3
Miscellaneous articles tested for length	60
Articles tested for angles	19
Articles graduated	43

Recommendations for Year 1920–21.

The work is increasing rapidly, and the manufacturers, dealers, and users are very urgent in their requests for promptness in the completion of tests. Even by working overtime all the tests can not be cared for. This increase applies particularly to sieves, haemacytometers, and tapes. (There are apparently some manufacturers who are using delays of past years as a basis for a propaganda that material, such as sieves, can not be standardized at the Bureau for many months, and therefore the customer should accept whatever the manufacturer wishes to sell him.) Every effort is being made to simplify and hasten the work, and additional assistance will be requested for it.

Publications.

Circulars 2 and 39 have been thoroughly revised during the past year, and it is hoped that they will be published within a short time.

Visitors and Travel.

Many manufacturers and others interested in certain phases of the work have consulted with the Bureau regarding their problems by correspondence and through personal visits.

MASS.

Requests for Tests.

During the past year there was an unprecedented increase in the number of weights submitted—about 600 in June, with a total of 5,795 for the year as compared with 3,452 for last year, an increase of almost 70 per cent.

This is not merely an increase over last year, but is about 60 per cent more than ever received before, while the large number of high-precision tests called for and the much larger average errors of the weights tested have increased the work to nearly, if not quite, double that required on the tests of any previous year.

Prompt Handling of Tests.

Prompt handling of the test weights was greatly facilitated by the adoption during March of the policy of making a final report or certification on each set of weights in the condition in which it reached the Bureau. By no longer holding sets for the maker or dealer to replace individual weights found unsatisfactory it was possible to keep the current work well up to date. By the close of the year all of the long-standing tests had been either completed or put in such shape that they will be completed during the next month. Since a couple of minor assistants have been secured the work has gradually been brought up to date. Instead of tests being in the Bureau from three to five months one-half of the 600 weights received during June were sent out during the same month.

Another aspect of the same change is shown in the reduction of the number of weights on hand. On September 1 there were 2,500 weights on hand: on November 8, 2,000; on April 24, 1,300; on June 30, 458.

For the testing of sets of analytical weights a regular routine was established. This provides for the complete testing of a new set each day, the weights being wrapped and sealed and the certificate written and checked generally on the following day.

By dividing the work so that no person puts all his time on simple routine processes it has been possible to make the whole work of the laboratory somewhat more flexible, and to avoid that deadening of interest that so commonly comes from routine work. The tests carried out during the year were received from the following sources:

	Percentage.
Federal Government	24
State governments	7
Educational institutions	4
Outside parties	65

Standards for States and Manufacturers.

Five sets of primary State standards were tested for the State of Oklahoma. Important State standards were also tested for Vermont, Massachusetts, and Missouri, and a set was received from Texas just at the close of the year.

The most important primary standards of two of the largest makers of weights were tested. Some of these showed changes which are probably responsible for excessive errors in weights submitted by these makers to the Bureau. A set was also tested for one of the comparatively new firms that had been having great difficulty with inaccurate weights.

Pyroxylin Plastics.

As a part of a general investigation being conducted by the Bureau on pyroxylin (celluloid and similar materials) the absorption of water has been studied for a number of samples of different thicknesses of this material from different makers. The absorption by pieces 15 centimeters square and from 0.15 centimeter to 1 centimeter thick was from 1 to 6 grams when the samples were changed from air of about 35 per cent to air of about 95 per cent relative humidity.

It takes several weeks for the samples to attain approximate equilibrium in air when the humidity is changed, and consequently the investigation is very long drawn out. A group of the heavier samples has been subjected to humidities from 35 to 97 per cent and back to 52 per cent.

Improvements in Observation and Computation Forms.

Further improvements were made in some of the forms used in routine testing and two new calibration schemes were developed. This work is of great importance as the proper arrangement of the forms often makes considerable difference in the time required for recording and computing the results. The scheme must also provide checks to detect any errors committed.

Personnel.

Eight new assistants have been started in the work of this section during the year. Of these, three stayed from one to three months.

Only one assistant has been in the section more than one year. The training of new assistants and planning the work so as to get the best results with their limited experience and skill has consumed much of the time of the experienced workers.

Since this work demands months of training to secure reasonable efficiency the changes in personnel have very greatly hampered the work.

TIME.

Testing.

This section has completed the following kind and number of tests:

Class A watches	25
Railroad precision watches	50
Engineers' watches (Army)	84
Ship watches	1,771
Comparing watches	1,435
Stop watches	7
Wrist watches	11,372
Deck clocks	1,491
Miscellaneous	142
Total	16,377

Railroad Precision Pocket Watch Specifications.

A series of observations on watches of various grades under new conditions, together with information from manufacturers and railroad inspectors, provided the basis for drawing up a new set of specifications for testing pocket watches. This "railroad precision" watch test as compared with other tests, is unusually short; nevertheless, it is possible to classify watches according to their quality correctly by this test, as has been proven later through elaborate investigations.

Stop Watches and Chronographs.

A number of stop watches and pocket chronographs were tested quite carefully, using new methods. As a result of this investigation it was shown that many of the best-made stop watches possess important errors which are directly due to manufacturing methods.

Specifications for purchasing stop watches have been prepared and are now in use.

Publications.

A new circular for jewelers' weights and measures to replace the circular (No. 43) on the metric carat has been nearly completed. When the tables in this circular are available, the workers in precious metals will be able to use the metric system for all purposes.

A few additional tables were prepared for a revised edition of Circular 47.

Travel.

An official visit was made to all of the watch factories in the United States and five of the general time inspectors of the various railroads. The information derived from these experts was used in preparing the specifications for railroad watches referred to

above. Also, a visit was made to New York and Waterbury, Conn., relative to the standardization of watch glasses. At the same time the needs of the workers in precious metals were studied. This resulted in the revision of Circular No. 43 referred to above.

Future Work.

About 50 per cent of the work of this section is the testing of timepieces which are being supplied on purchase orders of the Emergency Fleet Corporation; this will continue throughout most of the coming fiscal year.

The work of the War Department will continue for some months, but will be likely to decrease a little from that of the past year.

An investigation deemed advisable is the determination of a shorter commercial method for adjusting watches in the factory. At present one of the largest companies takes nine months from the time a watch is begun until it is completed. If part of this time can be eliminated it will be a great public economy.

Also, it is proposed to investigate the practicability of the use of some of the new metals and alloys in watch construction, including new types of construction. For this work a skilled watch mechanic will be required.

CAPACITY AND DENSITY.

Routine Testing.

Apparatus.	Number submitted.	Tested.	Passed.
Burettes	982	584	389
Cylindrical graduates	129	101	25
Cone	3	3	1
Dilution pipettes	1,210	1,189	1,036
Flasks	1,572	1,259	988
Pipettes, transfer	2,558	2,198	1,676
Pipettes, measuring	263	237	203
Total	6,717	5,571	4,318
Hydrometers	680	670	449
Salinometers	.....	[1] 238	.....
Capacity measures	.....	149	.....
Capacity measures (liquid field standards)	.....	29	.....
Density	216	216	.....
Special apparatus:			
Babcock glassware	120	60	59
Specific gravity flasks	18	18	17
Engler flasks	158	[2] 146	.....
Miscellaneous	181	181	.....

[1] Special. [2] Reports.

Sixty-four per cent of the volumetric glassware submitted passed the test, while of that actually tested 78 per cent passed. This is an increase of 13 per cent passing test over that reported one year ago. Of the hydrometers submitted, 66 per cent passed test.

During the year the number of pieces of glass volumetric apparatus submitted was 57 per cent more than for last fiscal year. The number of hydrometers submitted shows a decrease of 35 per cent, due to decrease in the use of alcoholmeters by the Internal Revenue Service during the fiscal year. While the number of hydrometers submitted shows a decrease, the amount of time required to test

these instruments was increased very materially on account of the greater variety of the hydrometers submitted.

Capacity and Density Determinations.

The number of metal capacity measures tested, certified, and sealed was 149, as compared with 48 the previous year, an increase of over 200 per cent.

The density of a number of samples of steel was determined for the metallurgical division of the Bureau to show the relation in density change due to a difference in quenching temperature.

Several samples of alcohol (both ethyl and methyl) were examined and their densities determined in connection with some work done by the physical chemistry section of the Bureau. Samples of sodium chloride solutions were examined, the results of which will appear in a joint paper by the heat division, the chemistry division, and this section.

Visitors.

Representatives from practically all of the makers and jobbers of glass volumetric apparatus who submit such goods for test visited the laboratory during the year in the interest of placing better ware on the market. Several sent representatives to the Bureau for training, to inspect the methods employed by the Bureau, and to prepare themselves for more satisfactory work. The Bureau has calibrated a number of the working standards used by the makers of glass volumetric apparatus in their testing rooms.

Information.

This section was requested by the Field Medical Supply Depot of the War Department to criticize and make suggestions for tolerances and specifications covering all of the apparatus tested by this section. This has been completed and in practically all cases suggestions were accepted without change. Blue prints were prepared of the flask standards used by the Bureau and sent to several firms requesting them for use in their testing laboratories.

Recommendations.

The Bureau, through a circular letter of June 15, 1920, discussed the advisability of discontinuing the certificate of corrections for glass volumetric apparatus (with the exception of burettes and measuring pipettes). A large number of replies have been received. and in practically all cases the parties agreed that if the precision stamp is placed on the apparatus it will not be necessary to furnish certificates. This proposition is recommended, and, if adopted, will facilitate the testing of glassware fully 40 per cent.

Investigations.

A request has been received from the department of standards and tests of the National Petroleum Association to determine the density and thermal expansion of petroleum oils beyond the density and temperature range as reported in Technologic Paper 77 and Circular No. 59. The samples for this work are in the laboratory,

but work has not yet been started, due to the urgency of the routine testing.

There are many demands for a publication giving the density and the number of pounds per gallon of such liquids as peanut oil, coconut oil, lard oil, molasses, sirups of various kinds, etc. This information is apparently needed by the industries of the country and attempts will be made to prepare such data at once.

Additional Space Required.

The work of this section is greatly hampered by the lack of space to calibrate and store the large quantities of apparatus submitted for test, and this contributes in no small extent to delay in disposing of tests. If the work continues to increase as it has in the previous year, which amounted to more than 57 per cent, it will not be long before the congestion becomes so great as to completely block the testing work. The space required for this work is not less than 50 to 100 per cent more than is now available.

GAS MEASUREMENT.

Orifice Meter Investigation.

The investigation of the characteristics of small orifices for air and gas has been continued, and, although valuable results have been obtained, the investigation has not been completed.

It is very desirable that the investigation be extended to the large orifices such as are used commercially in metering enormous quantities of natural gas, air, and other gases. Neither funds nor assistance to pursue this very important work have been available. The cost of this investigation would be only a small part of the annual saving which it would make possible through the conservation of natural gas.

Portable Cubic-Foot Standard.

The portable cubic-foot standard, developed by this section and dedicated to the public through a patent, is now being manufactured on a commercial scale by one or more firms, and the Bureau has cooperated actively in making it available to the public. These instruments are now being used by a number of different industries.

An investigation has been carried on to determine the applicability of the portable cubic-foot standard developed by this section to the calibration of the small-capacity laboratory meters or gas meters used for testing purposes. The results of this investigation show that the instrument is very well adapted to this work, as it is easy to quickly and accurately calibrate a test meter by the use of this apparatus at any of the speeds at which these small meters are ordinarily used.

New Method of Measuring Low Gas Velocities.

The accurate measurement of low gas velocities such as are used in ventilation is often a matter of great difficulty, and this is especially true when these velocities are below 3 or 4 feet per second.

This laboratory has developed a simple method of measuring such low velocities which appears to be very promising. Briefly, the

method consists of placing a dynamic tip in the air current of unknown velocity and another in an air current the velocity of which can be accurately regulated and connecting the tips to a suitable indicator. The secondary air current is then regulated until the indicator shows that its velocity is equal to that of the unknown air stream. In the experiments thus far made a glass T filled with smoke has been used as the indicator. Preliminary results indicate that velocities as low as one-half foot per second may be measured by this method with an accuracy of about 2 per cent.

Routine Testing.

The routine tests made by this laboratory on gas-measuring apparatus are shown by the following list:

Portable cubic-foot standards	8
Dry gas meters	7
Wet gas meters	1
Air-flow meters	2
Total	18

All of the gas meters and three of the portable cubic-foot standards were for the use of Government departments. The two air-flow meters were for use by the department of terrestrial magnetism, Carnegie Institution of Washington. The other instruments were from commercial concerns.

Consulting Work.

A considerable amount of consulting work on gas-measurement problems has been done during the present year. Those who have taken advantage of this portion of the section's activities have included officials of the War Department, Navy Department, other Government departments, and commercial concerns.

THERMAL EXPANSION.

Tests.

One hundred and thirteen specimens have been tested during the year, including research work on steel, enamel, porcelain, celluloid, molybdenum, brass, alloys, etc.

Carbon Steel.

The length changes of tempered steel have been studied over the range 20 to 950° C. It is thought that heat treatment near 200° C. will, in some measure, accelerate the dimensional changes which take place with time. The results indicate that much of this instability will be removed if the tempered specimen is held at 200 to 250° C. for a few minutes. The problem requires additional work to determine the exact maximum temperature and time allowable for this treatment without serious injury to the hardness. Stable material is essential to makers of length standards and gauges, and it is expected that the investigations in this field will indicate the best treatment to secure material of this sort.

The investigation of expansivities at the critical points is nearing completion and will probably be published during the coming year.

Stainless Steel, Monel Metal, and Stellite.

An investigation of the expansion of the above metals was undertaken to see if they could be used in conjunction with or in place of ordinary carbon steel. This research is practically completed and indicates no large variation of coefficient among these three materials of dissimilar composition. The range of coefficients extends from 10 to 15 parts in a million per degree centigrade.

Enameling Materials.

This division cooperated with the ceramics division in the study of spalling or "fish scaling" of enameled ironware. It was found that one of the causes of this defect is the divergence of coefficients of iron and the enameling compounds, and that by cooling the enameled vessels slowly it is possible to prevent this rupture between the iron and the enamel.

Large quantities of enamel ware are rendered useless by the scaling of the enamel from the iron body, and this has added considerably to the cost of manufacture and handling. It is hoped that this investigation will help to remove this difficulty.

Celluloid, etc.

A number of cellulose materials manufactured under various names, such as celluloid, viscolloid, pyralin, etc., were investigated. The expansion of these materials in all cases investigated was uniformly large and the tendency to permanent shrinkage quite noticeable when heated 30° or more above room temperature.

Brasses.

A series of alloys representing all the commercial brasses has been tested, and a circular describing the work is being prepared for publication. Equations and curves are given which will enable one to determine expansion coefficients from the chemical compositions of the copper-zinc alloys. Numerous photomicrographs showing metallurgical phases of these representative brasses have been furnished by the American Brass Co., and this firm has lent valuable aid throughout the research.

Molybdenum.

The nonuniformity of values given for the coefficient of expansion of this material led the Bureau to attempt an interpretation of these values. With the cooperation of the Westinghouse Lamp Co., tests were made on slugs of molybdenum. These were later drawn and reduced to a very small fraction of the original diameter, tests being made after each drawing. The variations produced by these operations will account for all discrepancies in values. The fact that mechanical treatment may modify the expansive properties is not new. The problem of the Bureau is to establish the definite relations, if possible, between the factors modifying these properties.

Glass.

The anomalous expansion of glass, occurring a few degrees below the softening point, which was discovered by the optical division, has been definitely confirmed by this laboratory. The method of measur-

ing specimens employed eliminates all possible errors due to oxidation or chemical reaction at points of contact with specimens. Likewise the error which would occur when specimens soften and start to collapse under their own weight does not affect the determinations.

Anthropometric Instruments.

The Bureau assisted in designing and constructing some anthropometric instruments which were required by representatives of the Smithsonian Institution. These instruments were formerly secured from Europe and are used in detecting certain physical characteristics of different races.

Dental Research.

The tests on dental amalgams by this and the optical division have been completed. Technologic Paper No. 157 describes instruments and methods for the most precise work in this field. Comparative data are included which indicate the presence, on the market, of some materials of very questionable value.

The Bureau is pleased to note improvements and increased activities, looking toward the highest degree of perfection, by numerous manufacturers.

The Bureau has received requests to extend this research into additional fields of dental science and it is hoped that opportunity will be found to furnish assistance to the profession in these other lines, where a large amount of confusion and indefinite data still exist.

Dividing Engine.

For various reasons little or no progress has been made on the new dividing engine referred to in the last annual report. In order to utilize to the best advantage the apparatus that the Bureau has on hand, the present equipment was overhauled and a slightly higher accuracy obtained. It is hoped that during the coming year it will be possible to devote some time to the development of an engine, which is not only needed by the Bureau but also by American industries. At the present time, it is practically impossible to obtain linear scales of high precision in this country.

COMMERCIAL SCALES.

Railroad-Track Scale Investigation.

The work of the railroad-track scale section has been very seriously hampered by the lack of sufficient funds to keep the testing equipments in the field at all times and also by the resignations of many of the men trained in this work who have left the Bureau to accept more lucrative positions with railroads, scale companies, and other industries. This turnover of personnel is very undesirable in this work since special experience is required, and it is difficult to procure men with the proper education and personal qualifications at the salaries that are available. As the result of recent resignations several men must be procured before all equipments can be put in operation. The congestion on the railroads also prevented prompt movements of equipments, and in one instance, during the switchmen's strike, one equipment was tied up for nearly a month while

the others were more or less delayed. The combined effect of the above causes has been more than equal to the laying up of one of the three equipments for the full 12 months.

During the first eight months of the year the Bureau continued its work in cooperation with the Railroad Administration and since that time has been making its arrangements in connection with the American Railroad Association and the individual railroads in the same manner as formerly. No difficulties were encountered as a result of the return of the lines to private control, the American Railroad Association having shown every desire to cooperate with the Bureau along the lines of the former agreement which has now been revived. It is now necessary to prepare schedules much further in advance than when the railroads were all operated by the Government, however. The work completed during the year may be summarized as follows:

Scales tested.	Number tested.	Correct.		Incorrect.	
		Number.	Per cent.	Number.	Per cent.
Railroad-track scales	438	189	43.2	249	56.8
Industry-track scales	114	44	38.6	70	61.4
Government and State track scales	8	1	12.5	7	87.5
Total	560	234	41.8	326	58.2

These tests were made in the following 31 States and the District of Columbia:

Alabama.
Colorado.
District of Columbia.
Florida.
Georgia.
Idaho.
Illinois.
Indiana.
Kansas.
Kentucky.
Louisiana.
Maryland.
Michigan.
Minnesota.
Mississippi.
Missouri.
Montana.
Nebraska.
New Jersey.
New York.
North Dakota.
Ohio.
Oklahoma.
Oregon.
Pennsylvania.
South Carolina.
Tennessee.
Texas.
Utah.
Washington.
West Virginia.
Wisconsin.

Among the scales tested were some of those owned by 88 different railroad lines and by many industrial establishments. As in the past, individual reports, including recommendations, were made on each scale tested to the interested parties. In many instances the Bureau is advised that its recommendations in the case of defective and incorrect scales have been complied with and that the scales are now weighing correctly.

Specifications for the Manufacture and Installation of Railroad-Track Scales.

In the preceding annual report reference was made to the subject of specifications for railroad-track scales. Since that time the most sanguine expectations have been realized, since the specifications have been officially adopted by the American Railroad Association; the American Railway Engineering Association; the United States Railroad Administration; the Scale Manufacturers Association; the National Scale Men's Association; the Bureau of Standards; and,

with a slight modification to adapt them to the particular use of weighing grain, by the State of Minnesota. They have been published by the Bureau of Standards as Circular 83, "Specifications for the Manufacture and Installation of Railroad Track Scales."

Specifications for Scales for Weighing Grain.

In the last annual report reference was made to the subject of scales for weighing grain, a matter of importance in connection with a case before the Interstate Commerce Commission, Claims for Loss and Damage of Grain, Docket 9009. Since that time the final hearing has been held and the decision rendered. The specifications for scales for weighing grain, prepared by the committee appointed for the purpose, and on which this Bureau was represented, were approved by the commission and are indorsed by this Bureau. This favorable action of the commission taken with respect to the specification appears to be regarded by those interested in the buying and selling of grain, including country elevators and terminal markets, as a distinct forward step toward securing the establishment of proper and adequate facilities for the weighing and handling of grain.

Master Scales.

The Bureau has continued its work of maintaining the standard of weight on the various railroad lines by calibrating and adjusting, when necessary, the master scales located in various parts of the country. These are the scales which are used to standardize the weight of test cars employed by a number of the railroads and industries to test the accuracy of their track scales. The accuracy of these scales is a matter of extreme importance since if not correct the cars calibrated upon them will not be correct, and the errors will be reflected in each scale tested by such cars. In the interest of track scale accuracy the Bureau calibrates all of these scales that are in condition once in each year. During the last 12 months 14 such tests were made, these including three new master scales just installed. Special investigations and tests of some of these scales have also been conducted.

Revision of Tolerances for Master Scales.

As a result of the work of the Bureau in standardizing the railroad master scales throughout the country, sufficient data have been accumulated to give information respecting the nature of the action of such scales, and the accuracy which could be obtained from present designs—information which did not previously exist. As a result of a careful study of the data, the tolerances for use in the adjustment of master scales have been revised; and these revised values have been accepted by the committee on scales of the American Railroad Association, and have been adopted by and printed in the proceedings of the American Railway Engineering Association.

In the new tolerances explicit distinction has been made between the tolerances for adjustment and the tolerances for maintenance. The tolerances previously applied were essentially tolerances for adjustment. In the new values for tolerance on adjustment the allowable error for the high loads is less than before, while for the lower loads they are greater than was previously the case. This change in

tolerance meets conditions found in practice in field work, and the new tolerance also corresponds in character and value with the requirements for which the scales are furnished. The tolerances adopted are as follows:

Test load pounds.	Tolerance in pounds.		Test load pounds.	Tolerance in pounds.	
	For adjustment.	For maintenance.		For adjustment.	For maintenance.
20,000	3.00	6.00	60,000	5.20	10.40
30,000	3.68	7.36	70,000	5.62	11.22
40,000	4.24	8.48	80,000	6.00	12.00
50,000	4.75	9.49	90,000	6.37	12.74

Test of Locomotive Scales.

During the first five weeks of the year one of the equipments was employed in calibrating special locomotive scales used in plants with which the United States Railroad Administration had contracts in order to assist in the proper settlement of contracts and claims. This work, which was started in the last fiscal year at the request of the Railroad Administration, was completed, investigations having been made in plants located in New York, Pennsylvania, New Jersey, Virginia, and Ohio.

Bureau of Standards Master Track Scale.

Attention is again called to the urgent necessity of providing for the installation and housing of the master track scale purchased several years ago. This is urgently required for the proper operation of all of the track scale testing equipments. Test cars Nos. 3 and 4 must be reweighed every two months or more in order to maintain and assure their accuracy, and this reweighing should be done on a scale operated and guaranteed by the Bureau. The 200,000 pounds of test weights carried on cars Nos. 1 and 2, which are used in certifying to the accuracy of every master scale in the United States, must be repainted and adjusted from time to time and the equipments overhauled. The Bureau has no present facilities for doing work of this character.

In addition to the needs of the Bureau, the proposed station would also be used for the standardization of the test cars of all railroads entering the city in which the scale is located, the calibration of weights carried thereon, as well as the calibration of all heavy weights submitted for test by industries or railroads located in the vicinity. The maintenance of a Government-owned master scale and testing depot at some central point would do more, perhaps, than any other one thing to furnish a correct standard of weight to be transferred to railroad-owned and industrial scales, to quicken the appreciation of accurate weights and weighing, and to reduce claims, allay suspicions, and provide a more stable basis for all business carried on by weight.

In the opinion of the Bureau the city of Chicago is the most favorable location in the country for the station, as it would serve a maximum number of railroads and industries.

Mine-Scale Investigation.

This work demands men of much the same qualifications as those employed upon the railroad track scale investigation. Therefore, what has been said concerning the hampering of the railroad scale work on account of the difficulty of holding and procuring a suitable trained personnel applies here with equal force. Resignations have been so numerous that it will be necessary to recruit and train several men before this work can again be prosecuted. Strikes also had the effect of curtailing this investigation, the general strike of the bituminous coal miners rendering necessary a complete cessation of the work, which had been prosecuted vigorously up to that time.

A total of 221 mine scales were inspected during the months in which the investigation was carried on. Of these, 72 scales, or 32.6 per cent, were found to be within the tolerance allowed on this class of scales, while 149, or 67.4 per cent, were in error by more than the allowable amount.

The experience of the Bureau during the preceding year enabled it to fix as a fair tolerance on these scales 0.4 per cent. This figure is twice the tolerance allowed on railroad-track scales. However, the conditions under which these scales are installed and operated are very unfavorable to continued accuracy and an analysis demonstrated that no injustice would be done by allowing the error mentioned.

As heretofore, the tests made were found to have a very favorable effect on continued production of coal. Many of the tests were made upon the request of miners or operators; in those cases where the scales were found accurate, distrust and suspicions were allayed in the minds of the workers and operations continued with better feelings on both sides; in other cases where scales were found to be inaccurate, corrective measures were applied and both parties to controversies satisfied.

This work was carried into new mining regions during the year, tests being made in the bituminous fields of Kentucky, Tennessee, Ohio, West Virginia, and Georgia.

COOPERATION WITH STATES AND OTHER INTERESTS IN WEIGHTS AND MEASURES ADMINISTRATION.

This work has been carried on for some years and primarily consists in making the Bureau of Standards a general clearing house for the dissemination of weights and measures information to the end that the State and local officials enforcing weights and measures laws may attain the highest possible degree of efficiency. Without correlation, laws, rules, regulations, and methods in the various jurisdictions will fail of uniformity, with the result that progress will be slower than would otherwise be the case and wasted effort the rule rather than the exception. In the meantime a useless and unnecessary burden must be borne by manufacturers of all kinds of products and commodities in their endeavors to conform with the varying requirements of the separate States.

National laws would solve many of the most pressing problems, especially a law giving to the Federal Government the right to pass upon the types of weighing and measuring devices manufactured for commercial use. The very great majority of State and local officials

are in favor of such a law and one or two States have endeavored to obtain some of the benefits to be derived therefrom by State laws recognizing the decisions of the Bureau of Standards in their jurisdictions. In the absence of Federal law, however, the Bureau is endeavoring to obtain the best conditions possible by the voluntary cooperation outlined above. The only fund available for such work is that granted for the inspection of railroad-track scales and other purposes, and, as is mentioned elsewhere, this fund is inadequate even for its major purpose. While it is recognized that the benefits of such cooperation are wholly incommensurate with the expenditures involved, it has been found impossible to prosecute it with any degree of vigor and what little progress has been made has been through the medium of State conferences and the national annual conference mentioned hereafter.

Representatives of the Bureau attended State conferences of weights and measures officials in Maine, Massachusetts, New Jersey, New York, Pennsylvania, and Wisconsin, gave addresses on timely subjects of importance, and rendered general assistance along the lines of weights and measures administration. Also, all possible information was furnished by correspondence where the nature of the case made it possible to assist in this way. In the case of the State of Maine which recently passed a law requiring manufacturers to obtain certificates of approval on their apparatus before it could be sold in the State, it was found necessary to advise the State authorities and the manufacturers that under present conditions the necessary inspections and tests by the Bureau preliminary to the issuance of such certificates could not be undertaken. Similarly, nothing could be done to assist the State of Texas, which has passed a permissive law along the same lines.

Thirteenth Annual Conference on Weights and Measures.

The annual conference on weights and measures is a meeting of State and local weights and measures officials who assemble at the Bureau of Standards for the purpose of gaining information of value to them in their various jurisdictions and to take action on matters of importance in their work of inspection of weights and measures and the enforcement of weights and measures laws. The thirteenth of these conferences was held at the Bureau on May 24 to 27, 1920.

One hundred and seven official delegates attended from 28 States and the District of Columbia, 22 States, 40 cities, and 29 counties being represented. Eighty-seven other interested persons registered and attended the sessions, these representing manufacturers of weighing and measuring devices, railroads and weighing departments, other Government departments, other associations, etc.

The greatest interest was displayed in the papers presented and in the discussions and debates. Among the subjects of especial interest brought before the meeting were sales by net weight, the standardization of loaves of bread and of commodities in package form, proposed legislation in reference to installation and testing of gasoline pumps, etc.

Specifications and Tolerances for Liquid-Measuring Devices.

Perhaps the most important single accomplishment of the conference was the adoption, after very thorough consideration, of final

specifications and tolerances for liquid-measuring devices. The constantly increasing use of gasoline, oils, etc., is resulting in a very great increase in the production and use of these machines, and the demand has resulted in there being put upon the market a very large number of types, some of which are objectionable on account of the fact that accurate measurement is not obtained or because their construction is such as to facilitate the perpetration of fraud. The various State and local departments have encountered the greatest difficulty in adequately handling the matter, and the need of uniform specifications and tolerances is very urgent. The action of the conference in adopting a final set of specifications and tolerances based upon requirements tentatively adopted by the twelfth conference will do much toward procuring the desired uniformity and thus making possible the securing of accurate and reliable devices in commercial use throughout the country.

Investigation, Inspection, and Test of Miscellaneous Weighing and Measuring Apparatus.

Investigations, inspections, and tests of scales and special machines were conducted by the Bureau for various other departments of the Government at their request. The navy yards at Norfolk, Washington, and Philadelphia, and the Marine Corps at Quantico, requested the inspection and tests of various scales and weights, and in pursuance of these requests, 189 scales and 44 weights of various types and capacities were reported upon. Scales and testing machines were also tested for various branches of the War Department, the Department of Agriculture, and the Customs Service of the Treasury Department. Special investigations on scales of various types were also conducted, to determine their suitability for various governmental purposes, such as for grading grain in connection with the enforcement of the grain standards act, for the Department of Agriculture, and for parcel post use for the Post Office Department. In connection with the inspection work at the navy yards the Bureau had occasion some time ago to inaugurate an inspection service at the Norfolk Navy Yard and instruct employees at the yard in proper methods of test to the end that regular routine inspections and tests of the weights and weighing devices at the yard might be made. During the inspections made this year this service was reorganized and strengthened, new report forms were prepared, and the work put upon a better basis. As a result of the work done in the Philadelphia Navy Yard this year it is probable that similar organization work may be requested there.

Various forms of large and small capacity automatic scales and packaging machines of new and unique designs have also been investigated and tested for industrial concerns. In connection with the preparation of specifications and tolerances for liquid-measuring devices various pumps and attachments have been inspected and tested.

Technical Subjects.

Many questions of a highly technical nature were handled during the past year. Owing to their nature, a great many of them represent work which is not completed, but on which studies must be continued, in some cases, for several years to come. An idea of the scope and

nature of such matters may be gained from the following list of subjects which received attention during the past year:

The effect of temperature on the action of dashpots and other damping devices; experimental set-up for research on dashpots; the locking of smooth pistons in smooth cylinders, under high pressures; viscous flow between two concentric cylinders, the inner one moving; alignment gauges for adjusting knife edges of weighing mechanisms; mathematical relations of interest in connection with the construction of certain precision variable angle blocks; the effect of a change of level on the balance of flexure plate scales and torsion balances; effect of eccentricity in a piston on the viscous flow between the cylinder and piston; the test of scales by taking readings by the method of vibration; a mistaken practice in adjusting grain scales; the precision test of automatic scales; determination of the formula for the error-versus-load curve, in tests made on master scales; the deflection of trussed levers, and the proportions for maximum stiffness; method for computing the error for any load from the results of the abbreviated added load test; eccentric circular cams for rectifying pendulum scales; influence of the stiffness of the tape on the action of cams, in weighing mechanisms; weighing by substitution; tolerances for automatic dial scales; the errors in the notches of scale beams.

Additional Space Required.

The division is greatly in need of a room on the ground floor of one of the Bureau's buildings in which the 10,000-pound precision platform scale and two equal-arm capacity balances, one 3,000-pound and one 1,000-pound, can be permanently installed. Such a room would then be devoted to the repair and calibration of heavy weights and in addition could be used for the overhauling of the mine-scale trucks and equipment from time to time. In the past there has been no designated place in which work such as this could be done. The result has been that the division has been obliged to borrow space from time to time and frequent movements of the scales and balances has been found necessary, an extremely inefficient method and one which has a very detrimental effect upon the equipment. This room must be readily accessible to automobile trucks so that weights can be delivered and removed, and should be equipped with an electric crane to facilitate the handling of the large weights.

GAUGE SECTION.

Routine Testing of Gauges.

The number of lots and the number of gauges submitted month by month during the year are shown in the following table:

Month.	Lots.	Gauges.	Month.	Lots.	Gauges.
1919.			1920.		
July	35	569	January	19	195
August	8	28	February	12	47
September	10	56	March	21	54
October	19	473	April	29	291
November	18	1,600	May	16	281
December	19	159	June	10	158
			Total	216	3,911

Of the above gauges, 76 per cent were submitted by Government departments other than the Bureau of Standards; 7.3 per cent by the Bureau of Standards; and 16.7 per cent by private concerns. During the year preceding 98.5 per cent of the gauges submitted were submitted by the various departments of the Government and only 1.5 per cent by private concerns. The total number of gauges submitted during the year previous was 40,630.

The very great decrease in the number of gauges submitted is significant of the tendency for manufacturers to revert to their old methods of manufacture without adequate inspection as soon as Government supervision is removed.

Need for Gauge Testing.

The need for gauges and gauge inspection did not cease with the ending of the war. Wherever interchangeable manufacture is carried on limit gauges are needed, and the adequacy of the gauging system employed may be taken as a fair measure of the success attained in interchangeable manufacture.

One of the principal reasons why the United States leads the world in the manufacture of automobiles, typewriters, machine tools, and other machine products is that manufacturers in this country have more nearly grasped the importance of gauging in interchangeable manufacture. It has been said that the wonderful production records made by our manufacturers during the war were due in a large measure to the fact that the United States Government insisted upon the proper use of gauges. The use of gauges is no less important in peace than in war and should be encouraged and fostered in every way possible. Manufacturers should not permit themselves to lapse into their old prewar methods with the resulting decreased production and increased cost.

New Type of Projection Lantern for Gauge Testing.

A projection lantern has been designed and developed of the type giving a straight projection on a vertical screen. This lantern has a greater magnification than has hitherto been employed for strictly gauge work and permits the operator at the lantern to see all the details of the projected image at a screen distance of only 3 or 4 feet. The reflecting prism and mirror of the vertical type of lantern are thus done away with. Furthermore, an arrangement for measuring angles is incorporated in the optical system of the lantern so that the protractor used with the vertical lantern is not necessary. The magnification of the lantern is sufficiently high to warrant its use in the measurement of the lead of thread gauges and the gauge holder is provided with an arrangement to permit the measurement of lead by means of gauge blocks and a micrometer screw. Also the lantern can be readily adapted to use for the optical gauging of machine products, especially threaded work.

Sine Plate Fixture.

A device based on the sine bar principle has been made, to facilitate the determination of the angles on profile gauges and templates. The device consists of two plates fastened to the opposite ends of a cylinder rotating in a V block. One plate is square and has four

one-half-inch buttons at its corners, the diagonal distance between centers of buttons being 5 inches. This plate and four buttons are essentially two 5-inch sine bars at right angles to each other. All the angles of a template or profile clamped to the other plate can be determined with one set-up, which is a great advantage over the ordinary sine bar. Due to the fact that the increment per minute for the natural sine of an angle is much smaller for angles of over 45 degrees than for angles under 45 degrees, angles greatly exceeding 45 degrees can advantageously be determined by shifting from one set of buttons to the other and greater accuracy can be obtained than with a simple sine bar of the same length.

Standard Method of Measuring Wires.

Considerable work has been done in standardizing methods of measuring the wires used in the 3-wire method of measuring pitch diameter of thread gauges. It is necessary to know the diameter and the variation in diameter of these wires to 0.00001 inch. To obtain this accuracy it is necessary to standardize both pressure and form and size of the contacts used. One of the Bureau's Anderson micrometers had been modified to give the desired pressure and contact conditions to measure these wires.

Investigation of Indicators.

An investigation of commercial indicators was started during the year. Measurements have been made on a few types of indicators and the hystersis loops plotted. It is to be regretted that no one is available at the present time to devote a large amount of time to this investigation and work of a similar nature.

Grinding Copper Eletroplates.

An investigation of the possibility of grinding copper electroplates was carried on in cooperation with the electro-chemistry section of the chemistry division. It was found that by the use of a surface grinder equipped with a suitable wheel and operated at the proper speed, copper electroplates could be ground to the desired thickness and planeness for use in a new process of plate making and that the method was sufficiently rapid to make it commercially feasible. On the basis of the work done at the Bureau, a plant was installed at the Bureau of Engraving and Printing, duplicating the grinding equipment used at the Bureau.

Publications.

The following communications have been prepared and issued during the year:

B522. Measurement of taper gauges.
B523. Thread measuring formulae and the measurement of pitch diameter.

B466 and B513 have been revised and a circular has been prepared for publication giving the results of an investigation and questionnaire on the subject of practical tolerances for plain gauges. The report of the National Screw Thread Commission has also been revised and several hundred mimeographed copies prepared and

distributed. The various communications of the gauge section dealing with the practical problems of gauges and gauging methods have been in great demand and many hundred copies of these communications have been distributed.

The National Screw Thread Commission.

The National Screw Thread Commission, appointed in accordance with an act of Congress (H. R. 10852), with the Director of the Bureau of Standards as chairman and with headquarters at the Bureau, has completed its principal work, namely the establishment of standards for screw threads for use in the United States, and has prepared for publication a very complete report setting forth the standards adopted. These represent the best American screw thread practice and involve no important changes except the elimination of unnecessary sizes. The report when issued will be an important contribution to American engineering.

Manufacture of Precision Gauge Blocks.

Twenty-five 81-block sets of precision gauge blocks have been made during the year and 19 sets delivered to the Navy Department; 15 sets to the Washington Navy Yard and 4 sets to the New York Navy Yard. The price of these blocks alone, if purchased at the price of foreign-made blocks of equal quality, would exceed by several thousand dollars the cost of operating the Bureau's shop for the entire year.

Optical Projection Lanterns for Ordnance Department of the Army.

An optical projection lantern of the new type already described was built for experimental purposes, and following that an order for six of these was received from the gauge section, Ordnance Department, U. S. A., of which one was completed prior to July 1 and the remaining five are now well under way.

Blocks for Experimental Purposes.

About 400 gauge blocks were made for the metallurgical division for use in an investigation carried out by that division in connection with heat treatment of steels. Blocks have also been made for the optical division for an investigation of the effect of various drawing temperatures on the hardness and permanency of length of hardened steel.

Experimental Apparatus.

The shop has also built other experimental apparatus for use in the laboratory; for example, the sine-plate fixture, the electrical-contact device for the Anderson micrometer, the magnetic faceplate for the lead tester, and miscellaneous odd jobs which were needed from time to time.

Exhibition of Gauge-Testing Equipment.

During the winter and spring of 1920 the Bureau participated in two exhibits of gauge-testing equipment. The first was held in New York, February 3 to 6, and the second in Detroit, April 14 to 16. At each exhibit manufacturers of gauges and gauging

equipment were well represented and an excellent opportunity was afforded for the Bureau to become better acquainted with the men and organizations most interested in gauging and for them in turn to become acquainted with the Bureau and its work. Both exhibits were well attended and successful in every way.

Travel.

In July and August, 1919, a member of the gauge section traveled in France and England in connection with the work of the National Screw Thread Commission and while there visited the International Bureau of Weights and Measures; the National Physical Laboratory; the London Board of Trade (standards office); and the Woolwich Arsenal. Several manufacturing plants in England were also visited. The experience gained is of very great value to the Bureau.

In September a trip was taken to New Haven, Conn., at the request of the Winchester Repeating Arms Co., to give a talk before their Engineers Club on the work of the gauge section. Opportunity was also afforded to study the gauging methods employed by that company.

In the latter part of June two members of the section visited Detroit, Mich.; Cleveland, Ohio; Flint, Mich.; and other manufacturing centers for the purpose of becoming more familiar with the problems encountered by the manufacturers of interchangeable products and with the methods employed by them in their solution. Opportunity was also afforded for the manufacturers visited to learn something of the Bureau and its work.

Several other trips were made during the year for the purpose of installing gauging apparatus furnished by the Bureau for the use of Government arsenals.

Gears.

One of the most important and most difficult problems confronting builders of machine tools and other machinery is that relating to the design, construction, test, and operation of gears. Comparatively little has been done on the subject, and the solution of some of the problems involved is of very great importance. It is hoped that a part of this work, especially that relating to the inspection and test of gears, may be taken up by the gauge section.

Heat Treatment of Gauge-Block Steel.

It has been found at the Bureau and elsewhere that precision gauge blocks of the accuracy necessary for the most exacting requirements can be made commercially by the process developed at the Bureau, but that blocks so made do not always retain their accuracy even when properly used or when not used at all. Certain blocks show a progressive shortening with time. These changes of length, though of small magnitude, are sufficient to cause uncertainty where the highest precision and constancy are demanded. An investigation is now under way, in cooperation with the optical division, to determine the proper temperatures for quenching and drawing the blocks in order that the desired hardness and permanency of length may be obtained.

Tolerances for Plain Gauges for General Engineering Work.

A subcommittee of the American Society of Mechanical Engineers has been appointed to study the above subject thoroughly and make recommendations to the American Engineering Standards Committee concerning tolerances for plain gauges for general engineering work. The gauge section is represented on this committee, and it is expected that the Bureau will have an opportunity to assist in the collection and classification of data and in the selection of tolerances to be recommended for adoption.

RECORDS.

The official records of the division, numbering of laboratory record books, and the assigning of computation number have recently been placed in charge of this section. A more complete and permanent method of keeping some of these records has been adopted and appears to be a very satisfactory one and a great improvement over the previous record.

The advisability of keeping a more complete record of the standards of the various States is suggested. This would have to be done in conjunction with the sections which test the standards. A file was made some years ago of the condition of the State standards from the reports of investigations, made by Bureau representatives, of weights and measures conditions throughout the States in 1909 to 1911. This record should be supplemented by reports from time to time from the State officials in charge of the standards and by adding to the record a report of the State standards tested and their condition, etc., at the time of test.

This section has cooperated closely with the laboratories in shortening their clerical and record work as much as possible by the use of proper forms and by lending assistance whenever it was possible to do so. Besides supplying stencil copies of numerous forms which have been in use for some time, assistance has been given in devising new forms. All of these forms facilitate the work of the laboratories and in many cases the time previously consumed on records in the laboratory has been reduced more than half by the use of stencil forms. The amount of time taken to prepare the stencil copies is a mere trifle compared with the saving effected in the laboratories by their use. It has also been found possible in a number of instances to prepare certificates and reports directly from the laboratory records, thus saving a large amount of time which was formerly taken to transcribe by hand the necessary data to the certificate and report forms, these in turn being merely copied by the office section. Some idea of the saving thus effected will be had from the statement that as many as 100 to 200 certificates or reports are prepared at one time directly from the laboratory records.

Weights and Measures Laws.

Eight years have passed since the last compilation of weights and measures laws of the various States and of the United States was issued. During this time very extensive changes have been made in the State laws; old legislation has been amended to meet present

conditions and the demand for greater protection and accuracy, and a number of States which had little weights and measures legislation at the time the last compilation was made have enacted laws upon broad lines for the protection of the consumer. These changes have made necessary a complete revision of the last edition. While considerable work had been done from time to time to keep abreast of new legislation, it was not deemed expedient to devote time to the preparation of a new edition during the war. However, opportunity was not found until last summer to devote much time to the revision of this work. It was taken up at that time and pushed during the fall and winter with as much vigor as the other work of the section would permit until the early spring, when matters relating to the annual conference on weights and measures had to be taken up. The revision is now nearly completed and will make a volume considerably larger than the former edition issued in 1912.

The weights and measures laws upon particular subjects should be compiled or abstracted, as may seem best in particular cases, so that a survey of such legislation in the various States can be had at a glance. Information of this kind will be of particular value when a State or a city is considering the drafting of legislation upon these topics and when enforcing laws relating to commodities which enter into interstate commerce. Such information has been compiled in a few cases, for instance, in regard to the sale of bread by weight and laws relating to the marking of the net weight of commodities in packages. As opportunity affords this work will be pushed.

Citations to Weights and Measures Cases.

Not infrequently requests are received by the Bureau from weights and measures officials and from other sources for references to court decisions on weights and measures cases. Opportunities are thus presented for the Bureau to give assistance to local sealers in a matter in which they are not well versed and in many instances have no other source from which to obtain the information desired.

Such information is usually required promptly and there is no time to search the records. As the particular subjects with which the local sealers are concerned can be anticipated to a large extent it is desirable that information on such subjects be compiled as early and as completely as practicable and be added to and revised from time to time. A beginning has been made in this work, but the field is a large one and a great deal of work will be required to collate a satisfactory file. The cases are being arranged for easy reference in three ways, namely, by States, by names of cases, and by subjects.

Foreign Weights and Measures.

The demand for complete and authentic information in regard to foreign weights and measures is constantly increasing; the Nation's expanding foreign trade has brought this subject more and more into prominence. The amount of reliable and up-to-date information published on this subject from private sources is not in keeping with its importance, and there is no government publication available.

The subject is an intricate one, requiring careful study, research, and, in some cases, investigation. A great deal of reliable data can

be gathered from reports and publications and by correspondence. It is evident, however, that it would be necessary in some instances in order to obtain the most reliable data and to ascertain the true situation, to make an investigation, since different units are used in different parts of the same country and units of the same name have varying values in different localities.

The Bureau has compiled considerable information from various sources during the past year, and has endeavored to render as much assistance as possible in response to inquiries from commercial and manufacturing concerns and from individuals. This work is a very important one and will be prosecuted as much as possible, but with a decreased force and lack of funds for this purpose it will be impossible to give it the attention that its importance and economic value to the Nation demands.

Kitchen Card.

A second edition of the Kitchen Card, Miscellaneous Publication No. 39, has been issued. This card has met with the hearty approval of chambers of commerce, home economics departments of schools and colleges, agricultural societies, weights and measures officials, etc. Nearly half a million of these cards have been requested, but due to lack of funds the Bureau has not been able to supply 10 per cent of this number, although the cost is very low, about 1 cent each.

2. ELECTRICITY.

The work of this division covers electrical units, standards, measuring instruments, and methods of measurement, including electromotive force, resistance, current, inductance, capacity, conductivity, insulation, magnetic measurements and properties, radioactivity, radiocommunication, and properties, and performance of electrical equipment, such as lamps and batteries. As a result of cooperation with technical societies, testing laboratories, electrical industries, public-service companies, public-utility commissions, municipalities, and engineers in problems of standardization, including standards of adequacy and safety of service, some of the work has been extended to cover more than strictly electrical service.

Scope of the Electrical Work.

One of the most important functions of the Bureau with respect to electricity and allied subjects is the establishment and maintenance of the fundamental standards upon which all electrical measurements are based, including cooperation with similar institutions in other countries so as to secure international uniformity. This includes the intercomparison of standards and extensive research in methods of measurement and the development and improvement of subsidiary and derived standards. These standards are utilized and the results of the researches are immediately applied in the testing of reference standards and instruments for manufacturers, testing laboratories, universities, research institutions, electric utilities, utility commissions, engineering and other interests, and various agencies of the Government.

The testing of electrical instruments and apparatus is of two main classes. First, there is the standardization of reference standards and precision instruments for manufacturing and other institutions which themselves make or standardize instruments for commercial use or which conduct research work. It is through the work of such institutions that the measurements made in practice are referred back to the standards of the Bureau. Second, a limited

amount of testing of commercial electrical measuring instruments, radio and photometric apparatus, magnetic materials, etc., is done, chiefly for the purpose of keeping the Bureau in touch with the needs of the industries, of developing methods, and of improving apparatus and materials. The greater portion of this testing is done for the Government services, and serves the double purpose of providing information to be used in formulating specifications and of determining the quality of materials furnished upon specifications.

The research work has mainly to do with methods of measurement, the determination of the electric and magnetic properties of materials, and the development of those phases of engineering science in which measurement plays an important rôle. Electrical, radio, and illuminating engineering interests are all served by these investigations. The Bureau also renders important service, both directly and indirectly, to manufacturing and other industries. Much of this investigational work is on the more fundamental aspects of the principles involved, so that the results may be applicable to a class of problems, rather than being limited to the one specific problem under investigation. The work on correlation of magnetic and mechanical properties of iron and steel and in the study of insulating materials are examples.

The research work in radiocommunication, magnetism, radioactivity, and photometry is along lines quite similar to that in the more purely electrical measurements. Standards have been and are being developed, methods of measurement are being improved, and important special problems of significance to the industries and in a number of cases of particular importance to the Government, are being investigated. Specific examples of the projects in hand during the past year are given in the sections below.

STANDARDS OF RESISTANCE.

Resistance Standards.

The need for better resistance standards is becoming more and more urgent as the range of electrical measurement is extended and applied in various fields. Especially is there a need for better low resistance standards capable of carrying large alternating currents and of high resistance standards suitable for use with alternating currents. Investigations are under way having for their object improvements in resistance standards for both of these purposes.

A new form of construction for wire resistance standards has been devised. This involves the use of a new type of noninductive winding on an insulating support and hermetically sealing the coil thus formed in an insulating case.

It has been found that by the use of forced air circulation the heat dissipated from a given surface at a given difference in temperature from the surroundings is very much larger than with natural convection. It has been found possible to make noninductive low resistance standards capable of carrying alternating currents without oil immersion and without making them larger than the oil immersed standards now in use. The elimination of the oil is not only a great convenience, but it eliminates the uncertainty incident to its use because of its tendency to develop acids which corrode the resistance material and thus change the resistance.

The investigation also showed that it was possible to change the electrical properties of small resistance wire by surface treatment. In many cases this will make it possible to improve the quality of a particular wire which is to be used in the construction of resistance standards.

Methods of Measuring Heavy Current Resistance Standards.

The problem of measuring the resistance of heavy current standards, using an alternating test current, has been investigated and a method of procedure outlined. A preliminary design of the necessary equipment for this work has been finished. It is expected that the new equipment for this class of work, when completed, will greatly expedite the testing of heavy current standards and will facilitate further investigation of means for improving the design of such standard resistors.

Resistance of the Human Body.

Most if not all measurements of the resistance of the human body previously made have included the resistance and often the apparent resistance of the skin, where the electrical connections were made. The values obtained have depended to such an extent upon the condition of the skin, area of connections, and other factors that no conclusions could be drawn from them concerning the resistance of any particular part of the body other than the skin.

By using four connections to the body, and suitable methods of measurement, resistances have been determined which do not include the resistance of any of these connections. The values found, using a test current of low frequency and of only a few milliamperes, have been definite and independent of the frequency and magnitude of the test current and other conditions of measurement. Using a hand and a foot as current terminals and the other hand and foot as potential terminals the resistance found, which is the resistance of the trunk of the body, for most individuals is between 20 and 30 ohms.

It seems probable that the resistance depends upon pathological conditions, and if so measurements of the resistance should furnish a convenient means for indicating changes in those conditions.

The resistance from hand to hand, using some of the fingers of each hand as current terminals and the others as potential terminals, has also been measured and it is entirely practicable to measure the resistance of other parts of the body. The resistances through portions of the skin are not included and consequently the resistance measured in this way is very nearly the same as that which determines the current in case of accidental connections between the body and high-voltage circuits, since then the skin is usually severely burned, so that it no longer has a high resistance.

INDUCTANCE AND CAPACITY.

Inductance and Capacity Laboratory.

The routine testing which is required of this section is increasing very rapidly. The amount of testing this year is 60 per cent greater than the amount last year, and considerably more than double that

of any preceding year. A great majority of the tests can not be made in any other laboratory in this country. Hence it is important that the laboratory shall be allowed to expand, so that these tests can be properly handled. At the present time it is frequently necessary for a test to wait one or two months because of the large number of tests which have been requested in advance of it.

Inductance Research.

Since most of the time of the personnel of the inductance and capacity laboratory has been taken up with routine testing work comparatively little research has been accomplished during this year. A paper entitled "An Integration Method of Deriving Alternating Current Resistance and Inductance of Conductors" has been published and work has been started on measurements for checking accurately the formulas given in this paper. Moreover, the formulas derived are rather complicated and difficult of computation, and an attempt is being made to construct a table which will very greatly facilitate this work.

Ballistic Investigations.

The ballistic investigations which the section has been carrying on for the Bureau of Ordnance, Navy Department, have been continued throughout the year. These investigations were carried on at the Bureau of Standards because of the precision measurements involved, particularly those of time and pressure. The Navy Department has provided the necessary facilities for conducting the experimental work, both at the proving ground and on battleships. The main problems investigated during the year have been as follows:

Study of the Variation of Gun Pressures with Time.—The experimental gauge which was designed last year has been thoroughly tested in a bomb and has been given a preliminary test in a 5-inch gun. Curves showing the results obtained have been plotted, and a report is being prepared for the Navy Department. This work is of the highest importance and will be pushed vigorously.

Primer Explosion Times.—The Bureau of Ordnance has furnished a large number of primers of different ages to be fired. The greater number of these have been fired in the laboratory, and data have been taken to determine their deterioration with age. The report on this subject will be delayed until after more urgent work is completed.

Ejection Velocities.—A method suitable for use on battleships has been devised which gives the velocity of the projectile on leaving the gun with an accuracy of approximately 1 per cent. It is believed that certain improvements which are now under consideration will give an accuracy of at least one-half of 1 per cent. It is expected that there will soon be an opportunity for testing this method in comparison with other methods.

Study of Recoil.—New recoil meters have been built which are much superior to those used in the early experimental work. A very large amount of data is now awaiting computation.

The Acceleration of Recoil.—By two differentiations of the curves obtained by the recoil meter, it is possible to obtain the acceleration of the gun in recoil. A study of these curves as obtained in the *New Mexico* firing shows such considerable variation in acceleration

that it seemed advisable to study the acceleration more directly. Hence for the *Sao Paulo* firing a special accelerometer was constructed. This instrument apparently functioned very satisfactorily, but as yet the Bureau has not had an opportunity for plotting curves and comparing them with the acceleration obtained from the recoil-meter curves.

Firing Time Intervals.—The study of the physical firing time intervals has been continued throughout the year, both on board and at Indianhead, Md. This has shown how to divide the process which takes place in the firing of the gun into certain subintervals to which study can be devoted.

Jump and Whip of Guns.—This work has been continued throughout the year. New kinemeters have been constructed which gave better results than those previously used in connection with the experiments on the *Sao Paulo* these measurements were of special interest on account of the very large whip of the turrets.

Velocity of the Projectile Inside the Bore of the Gun.—The Coast Artillery has cooperated in the design of a camera for determining the velocity of the projectile inside the bore of the gun. The camera is placed inside a shell and photographs a spot of light as the shell passes down the bore of the gun. In the first trials the lens of the camera was shattered because of the extremely rapid acceleration of the shell. New apparatus has been completed which will be tried in the near future.

This section has been designing apparatus for determining the velocity of the projectile from observations of the expansion of the gun. This was tried on the *Sao Paulo* firing with partial success. However, the apparatus has been considerably improved and it is hoped to be able to try it in the near future under more favorable conditions.

Blast Investigations.—This work appears to be of much less importance now than it did a year ago. It was then believed that the blast from one gun might influence the movement of the projectile from the adjacent gun. However, the data which have been obtained of other phenomena seem to indicate that this seldom, if ever, occurs.

Photography of Projectiles in Flight.—A camera has been designed and built for obtaining pictures of projectiles in flight. It was recently tried out at Indianhead, and gave very excellent photographs of the projectiles. This camera opens very important fields for investigation.

New Mexico Report.

The scientific data obtained for the Navy on the battleship *New Mexico* in October, 1918, and July, 1919, have been carefully compiled and a report of nearly 200 pages prepared. The distribution of this report is in the hands of the Bureau of Ordnance, Navy Department.

Measurements on the Battleship "Sao Paulo."

The Bureau of Ordnance of the Navy Department requested that measurements similar to those made at the time of the experimental firing of the U. S. S. *New Mexico* be made on the Brazilian battle-

ship *Sao Paulo*. A party of seven from the Bureau of Standards went aboard the *Sao Paulo* in New York on January 16, 1920, and left her at Guantanamo, Cuba, February 21. The firing took place at Guacanayaba Bay, where conditions are extremely favorable for such work. Every facility was offered to the Bureau's representatives by the officers of the ship, and a large amount of valuable data was obtained. Some of the data have already been compiled but a large part of it has not yet received attention.

Submarine-Mine Investigations.

Improvement in Mine Detonators.—At the request of the Bureau of Ordnance, Navy Department, this section undertook the study of the improvement of a special type of mine detonator. While this work is confidential, yet it may be said that a mathematical solution has been obtained which will be of very considerable importance in the design of such an apparatus.

Study of Soluble Washers.—The Bureau of Ordnance of the Navy Department has requested that a study be made of delay devices suitable for use in submarine mines. They ask that special attention be given to soluble washers. Apparatus has been designed and experimental work started on certain phases of this investigation.

Study of Recent Scientific Developments in France and England.

The chief of the section returned from France and England July 5, 1919, and immediately prepared a report covering his observations. This report was blue printed by the Navy Department and quite widely distributed for the information of their officers.

ELECTRICAL MEASURING INSTRUMENTS.

Testing of Electrical Instruments.

The volume of testing for the public was much larger than for the preceding year, and that for the Government was considerably less. It was necessary to spend a considerable amount of time in putting the Bureau's standard apparatus in condition after a certain amount of unavoidable neglect during the war.

The testing of instrument transformers has been continued during the year, and a detailed study of the standard transformers in use by this section is being made to enable the range of testing to be extended fourfold (up to 100,000 volts) by the use of series connections. This increase in range is very necessary in view of the high voltages at which large amounts of power are now being transmitted.

Electrical Properties of Ignition Apparatus.

A considerable variety of spark plugs have been investigated and the porcelains used in their construction have been tested as to their insulating properties, for various branches of the Government, as well as a number of commercial concerns which desired to undertake the manufacture of spark-plug insulators.

An intelligent study of the performance of ignition apparatus under various adverse conditions requires a fairly definite knowledge of the processes going on within the apparatus. Our knowledge of these processes has in the past been rather scanty, and expressible

only in extremely complex mathematical formulas. During the past year a somewhat simplified mathematical theory has been developed and found to give results in satisfactory agreement with experiment.

At the request of the Motor Transport Corps of the Army specifications were prepared for the testing of spark plugs, and these have been adopted by all branches of the War Department. A similar set of specifications for magnetos is in preparation.

Cooperation with American Institute of Electrical Engineers.

At the request of the instruments and measurements committee of the American Institute of Electrical Engineers, an exhaustive paper was prepared on the subject of the accuracy of commercial electrical measurements. This paper treats of the means by which accuracy may be obtained, such as by proper choice of instruments for a given service and by protection against adverse conditions likely to be encountered. A number of features of design are treated in their relation to the accuracy obtainable. This paper was read and discussed at the February convention of the institute, and copies have been sent to instrument specialists here and abroad in order to secure criticisms and additional information which will be used in preparing a revised and enlarged version to be issued as a Bureau publication.

The adoption of a standard definition of power factor in polyphase systems is of considerable commercial importance because of the increasing development of railway and arc furnace loads. At present different power companies base their charges for power on different definitions for this quantity, and consequently much confusion and injustice has arisen. The Bureau has cooperated with a joint committee of the American Institute of Electrical Engineers and the National Electric Light Association, and a detailed analysis has been made of the various possible definitions of power factor and of the related quantity "balance factor." The results of this study are incorporated in a paper to be presented at the summer convention of the American Institute of Electrical Engineers, and it is hoped that they will satisfactorily reconcile the somewhat conflicting requirements of the commercial and engineering users of this term.

New Apparatus for Electrical Instrument Testing.

Two commercial electrical instruments having promising features of construction were studied to determine their suitability as a basis of design for sensitive pivoted galvanometers. One of these was selected, and several galvanometers were computed from it. It is expected that the production of these galvanometers will make possible a considerable simplification and reduction in size and cost of the deflection potentiometers now being made from the original designs prepared by the Bureau.

MAGNETIC MEASUREMENTS.

General Magnetic Measurements.

In addition to the usual routine testing, a method has been developed and apparatus constructed for the measurement of normal induction and hysteresis at very high values of magnetizing force.

Measurements can be made with this apparatus up to a magnetizing force of 3,000 gausses. This work has been described in two scientific papers under the titles "Magnetic Testing of Straight Rods in Intense Fields," and "Measurement of Hysteresis Values from High Magnetizing Forces."

A study has also been made of the variation of residual induction and coercive force with the maximum magnetizing force. It was found that there are straight-line relationships between the maximum magnetizing force and the quotients of residual induction and coercive force by the maximum magnetizing force. These results were presented in a scientific paper entitled "The Variation of Residual Induction and Coercive Force with Magnetizing Force," which is now in press.

Magnetic Analysis.

The value of magnetic analysis both in the realm of pure research and in commercial testing is becoming more and more apparent as the development of the subject progresses. The need for such methods in the field of testing is evidenced by the growing interest on the part of manufacturers and users of steel, and the results of investigations already completed and now in progress indicate that we may confidently expect great savings, both in life and in money, when the relationships between the magnetic and mechanical properties of steel are sufficiently well understood to permit of their utilization to the fullest extent.

The work in magnetic analysis can best be described under four heads—correlation of properties, thermomagnetic analysis, testing of steel products, and detection of flaws and inhomogeneities.

Correlation of Properties.—The correlation of the magnetic properties with the structure and mechanical properties of steel is fundamental and underlies all practical applications of magnetic analysis. During the past year considerable progress has been made in the study of a simple carbon steel of eutectoid composition (0.85 per cent C). Special attention has been given to the development of the "reluctivity relation" as indicative of the microstructure. A paper is in preparation presenting the results thus far attained.

The section has been fortunate in obtaining from the metallurgical division samples of a series of pure alloys of iron, carbon, and manganese. These samples are nearly all prepared for testing. They will be tested after various heat treatments in order to correlate the magnetic properties with the various structures resulting from heat treatment.

Thermomagnetic Analysis.—Not only can the magnetic properties of steel be used as criteria of the structure and properties of steel, but they can also be utilized to detect structural transformations in steel on heating and cooling. By making simultaneous magnetic and temperature observations it is possible to determine the temperatures at which these transformations take place. It is also possible that information may be gained as to the nature of these transformations. Apparatus is now being constructed for making such observations and it is hoped soon to have some preliminary results.

Testing of Steel Products.—Although no definite practical applications have been established in the testing of manufactured prod-

ucts, a considerable amount of data has been obtained on the possibility of making useful tests of articles such as razor blades, armor-piercing bullet cores, and the like. The work on bullet cores was done in cooperation with the Ordnance Department of the Army, and it has been found possible to differentiate by means of a magnetic test between bullet cores having different structures and mechanical properties. The further development of this method for the testing of steel bullet cores has been requested by the Ordnance Department.

Detection of Flaws and Inhomogeneities.—The method for determining the degree of magnetic uniformity along the length of a steel bar which was developed some time ago has been modified and improved and has recently yielded some interesting and valuable results.

A series of carbon steel bars was examined which was intended to be used in an investigation on the effect of heat treatment on the mechanical properties. Certain portions of the material were located which showed variations in magnetic properties compared with the rest, and these were cut out so as not to introduce an extra variable in the experiments.

This method has also successfully located "soft centers" and segregations in bars of high-speed steel, and it is to be given a practical test at the plant of a steel company which has offered its facilities in cooperation with the Bureau.

A cooperative investigation with the Navy Department has also been undertaken for the purpose of adapting the method to the inspection of stream-line wire for airplanes, and promising preliminary results have already been obtained.

Magnetic Compasses.

A paper is in press on the testing of magnetic compasses. A small amount of work was done on compasses during the year, mainly in response to requests from the military branches for specific information regarding materials or design.

PHOTOMETRY AND ILLUMINATING ENGINEERING.

Heterochromatic Photometry.

Probably the greatest difficulties of precision photometry are encountered in the measurement of lights of different colors. These difficulties arise from the different estimates of equal brightness, minimum flicker, or other criteria of balance on the part of individuals of different color perception. The subject of heterochromatic photometry has assumed increasing importance with the advent of the highly efficient illuminants of the present time and much work has been done by many investigators throughout the world, with the end in view of establishing a satisfactory method of procedure for these measurements. In order to assemble the results of these experiments in such form as to provide easy reference to all articles of value on this and directly related subjects, a search was made of all available periodicals and textbooks, and a complete index of the subject was prepared with abstracts of all important articles and a convenient system of cross reference.

There is thus available a résumé of what has been accomplished and a ready means of deciding upon the course of future experiments. Pursuant to these activities a new series of experiments has

been begun, continuing work along the line carried out in the research made several years ago at the suggestion of the Illuminating Engineering Society. This research included measurements involving color differences on a flicker photometer and a contract photometer. The present study has been begun by the calibration of a series of blue glasses of graded densities at several illumination levels. Eventually these glasses will probably be sent to other laboratories for similar tests, and from these comparisons additional data of value regarding reproducibility, precision, and correspondence of results by the two methods of photometry should be obtained.

Inspection and Life Tests of Incandescent Lamps.

Departments of the Government placed orders for about 1,500,000 lamps during the year. This reduced quantity, which is considerably below the prewar normal of over 2,000,000, may no doubt be accounted for by accumulation of stocks of lamps carried over from the high averages of war-time production and the overflow of lamps already ordered and manufactured just previous to the armistice. Quantity figures, however, are of a different significance than formerly, because of the increasing use of the larger and more efficient units. For example, the average gas-filled lamp on these orders gives as much light as six vacuum tungsten lamps of the common 40-watt size, and, by a similar comparison, a single 1,000-watt gas-filled lamp is equivalent to 50 of the 40-watt lamps. Consequently, although in point of numbers orders for gas-filled lamps have reached only 16.5 per cent of the total for large tungsten lamps, the corresponding money value is about 45 per cent. As large tungsten lamps comprise somewhat over 80 per cent of the grand total of all classes, it is estimated that at least half of the total illumination realized from lamps on these orders is furnished by gas-filled lamps. In view of the unusual requirements of lamp service in some departments, this is a creditable showing. Orders for carbon lamps and for those of the miniature class made up the remaining 20 per cent in the proportion of about three to two.

Inspections to a total of about 1,200,000 were handled by the Bureau inspector at the factories of the contractors. The one inspector has been able to give prompt attention to all lamps on which inspection was required, but any considerable increase in the quantities ordered will necessitate the help of an assistant inspector in the field for at least a part of the year.

About 2,070 lamps were completed on the life test. This total includes 292 miniature lamps operated on the new racks and 163 of the same class, but rated at 80 to 130 volts, which were tested in adapters on the regular lamp racks. Of the remainder, 1,165 were vacuum tungsten, 225 gas-filled tungsten, and 325 carbon lamps.

The new life-testing equipment for miniature lamps is so arranged that tests may be made at any voltage from 0 to 24 and on either direct or alternating current. The primary winding of a 1 kilovolt-ampere induction feeder regulator is connected to the 120 volt mains, and it in turn controls the primary of a 10 to 1 step-down transformer. Three of these regulators are in operation. There are also three transformers of 1,600 watts, 50 cycles, two of which step down from 120 to 4 volts and the third from 120 to 2 volts. By control of

the primary voltage of these transformers the fractional voltages for life tests of flashlight lamps may be obtained.

For the direct current tests a number of Edison storage batteries rated at 6.5 volts, 30 amperes, 150 ampere-hours are available. The alternating current equipment is most convenient and economical for use during the regular testing season when the 120-volt alternator is in operation for tests of other lamps. The direct-current equipment is well adapted to operation during the summer months when the relatively small load of miniature lamps makes it inadvisable to supply current from the alternator.

Besides the regular inspections and tests, data upon the quality of lamps supplied by two prospective bidders on Government contracts were obtained and reported to the General Supply Committee. These results were given due consideration by the committee in making awards.

Interlaboratory Comparison of Life-Test Rating of Incandescent Lamps.

During the year the Bureau participated in two interlaboratory comparisons of ratings of lamps for life-testing purposes. Before the lamps are put on the racks for the burning tests they must be very carefully tested for candlepower and efficiency, since the life of a lamp depends on the efficiency at which it is burned. Life tests are usually made at efficiencies higher than normal in order to get results quickly, and since an error in the intial rating of the lamp makes an error several times as great in the corrected life, it is evidently very important to have the initial rating correct. There are a number of laboratories in this country doing work of this nature, and these tests were initiated to compare the ratings assigned to lamps by various laboratories. A number of lamps were measured in several of the laboratories, and the results were then compared. Later a much larger group, consisting of about 120 lamps, was submitted to the Bureau for similar tests. They were given a precision standardization, and were then measured in the same manner as ordinary life test lamps. They are now being measured in the other laboratories, and will later be returned to the Bureau for rechecking. It is hoped that by such tests the various laboratories may be brought into closer agreement.

A New Reflectometer for the Measurement of Diffuse Reflection Factors.

The measurement of the light reflecting value of walls and ceilings is of great practical importance in the design of lighting installations. The measurement of reflection factors of other surfaces is also desired at times. In the past there has been no simple and accurate instrument for this purpose, and all such measurements had to be carried out in the laboratory. Even then they were often incorrect. Several years ago the theory of an absolute reflectometer using the principle of the integrating sphere was worked out and an experimental instrument was constructed. During the past year this reflectometer has been very thoroughly tested and found to give accurate results. The instrument can be adapted for use with a portable photometer and can then be used anywhere for the measure-

ment of the reflection factor of any accessible surface. For example, accurate measurements can readily be made on the walls of a room, so that it is not necessary to prepare special samples of the wall finish for laboratory measurements. A scientific paper describing the instrument is now in the press and will be issued shortly.

RADIO RESEARCH AND TESTING.

Radio Research and Information.

The special research work undertaken for the Signal Corps in 1919 was completed. This included the following problems: Harmonics in electron tube generators, critical study of Signal Corps testing sets for electron tubes, input impedance of tubes used in amplifiers, detector action of receiving tubes, variation of direction of radio waves with time and the surroundings of the receiving aerial, properties and design of coil aerials. Reports were made to the Signal Corps, including 30 technical reports.

Since the completion of the Signal Corps work a wide range of research work has been carried on upon radio wave phenomena, antennas, electron tubes, amplifiers, radio telephony, insulating materials, and numerous radio instruments and measurements.

University Research Cooperation.

Assistance was rendered a number of universities in connection with research on radio problems. Transmission experiments on properties of radio waves were carried on with one institution. Research problems were suggested to a considerable number of university workers upon such subjects as electron tube detectors, electron emission, circuit design for radio telephony, electron tube measurements, and wave radiation. Information was given on laboratory equipment. Technical reports and miscellaneous information were supplied to a number of inquirers. Criticisms were prepared on a few scientific papers and books which were submitted. Advice was given on radio textbooks. "The Principles Underlying Radio Communication," which was prepared at the Bureau last year, is coming into wide use as a textbook both for elementary electricity and radio.

Standardization of Nomenclature, etc.

Studies were made of current practices in radio terminology, abbreviations, symbols, and notation. Information on this subject was furnished to a number of inquirers, and a standard terminology was adopted for use in the laboratory. The general adoption of standards of this sort was furthered by cooperation with the Standardization Committee of the Institute of Radio Engineers.

Publications.

A list of the radio publications of the Bureau was prepared. Lists were prepared of the technical reports of the laboratory; these reports, describing much of the research work that has been done, are available in limited number and have been sent upon application to specialists who are engaged upon the subjects treated. Publications have been issued or are in preparation on the various researches

described below. Second editions are in preparation of the two principal publications of the laboratory, Circular 74, "Radio Instruments and Measurements," and the textbook, "The Principles Underlying Radio Communication."

Exhibits and Nontechnical Descriptions of Work.

Many persons have visited the radio laboratory. The laboratory and certain exhibits have been specially equipped for the information of visitors, and have thus been of considerable educational value. Three lectures of popular grade were given on the principles of radio telegraphy and telephony. Thirty-seven nontechnical reports on the radio work were prepared, and a general description entitled "Bureau of Standards' Radio Work" was published.

Clearing House of Radio Information.

In prosecuting its research work, the radio laboratory has accumulated a large amount of technical information which has been carefully filed and has been found to be valuable for the use of the public. A file of references to radio articles and periodical literature is maintained and contains 7,500 references. Weekly reference lists are prepared. A subject classification for the whole radio field has been devised and discussed with various specialists. It has been used to index correspondence, reports, references, and data of many kinds. A number of bibliographies on special subjects have been prepared, particularly extensive ones on insulating materials and electron tubes. Copies of about 1,000 patent specifications have been secured and filed and comprehensive lists of these prepared on specific subjects.

A considerable part of the work is consulting service and the preparation of technical letters. The information furnished by letter and to visitors has been on such subjects as insulating materials, crystal detectors, cathode-ray oscillograph, electron tubes for particular purposes, amplifiers, radio telephony, testing methods, high-voltage direct current generators, mica condensers, measurement of capacity, theory of radiation of electric waves, and general information and photographs and other material on the radio work of the Bureau.

Research Program.

Definite programs of work have been prepared covering an extensive field of research, which is necessary for the advancement of radio and the general field of electrical communication. Statistics show that the growth of radio industry and operation has been very rapid in comparison with the accomplishment of necessary research. The Bureau is finding it difficult to do its share of this research work because of serious losses of personnel. One of the principal needs at present is the publishing of the large amount of technical and scientific data which is available.

Transmission Experiments.

Transmission experiments were carried on, the current in both transmitting and receiving sets being measured. A special type of electron-tube transmitting set designed at the Bureau was used in these tests as well as a spark set. The same transmitting equipment was used in experiments to assist the Aerial Mail Service of the

Post Office Department in developing airplane radio apparatus. Studies were made of the nature and amount of radiation of waves from various types of antennas. A scientific paper describing this work and giving definite transmission formulas was issued, and two lectures were given before scientific societies on the same subject.

Variations of Wave Intensity and Direction.

A series of tests was begun, with the cooperation of the American Radio Relay League, to obtain data on the rapid variations of signal intensity in short-wave transmission. The work has been carried on since June 1, 1920, the wave length used being 250 meters. Nightly records of the intensity of signals received from six transmitting stations are taken by 50 receiving stations. The stations are nearly all those of radio amateurs and are located all the way from St. Louis to Boston. Valuable data are being obtained on atmospheric disturbances as well as on signal intensity.

Reports were prepared upon experiments on the variation of direction of waves as observed by a coil direction finder. These included work on the variation of direction with time and effect of surroundings upon the observed direction of radio waves.

Measurement of Received Current and Signal Intensity.

A study was made of the various methods of measuring signal intensity and received current and voltage. Experiments were made upon the comparative signal intensity from various types of transmitting sets which give different signal wave forms, such as sine wave, damped wave, and interrupted wave of constant intensity.

Properties of Antennas.

Formulas were worked out by which antenna capacity can be calculated from measured dimensions. Measurements were made upon antenna ground resistance. Studies were made of such special types of antennas as the ground antenna, condenser antenna, and coil aerial. Reports upon an extensive research on the properties of coil aerials were prepared.

Electron Tubes.

The electron tube is a device developed within the past few years, which has revolutionized and greatly simplified radio communication. It is used for such diverse purposes as the production and reception of radio signals, amplifiers for magnifying electric currents and reproducing speech or other sound at great distances, telephone relays and repeaters for long-distance telephony, multiplex telephony, improvement of railway block-signal devices, the reduction of interference in radio communication, and radio telephony.

Electron-Tube Measurements.

The characteristic properties of typical tubes of various manufacturers have been measured. Permanent circuits have been designed and installed for measuring the important coefficients of tubes. Progress has been made upon the calculation of the coefficients of tubes from their dimensions. A comprehensive file of information on electron tubes, has been built up. A treatise on

electron tubes has been outlined in detail and the preparation begun. This is to give general information on the properties and uses of electron tubes, including much material hitherto unpublished. Its preparation has involved a special study of the physical phenomena in electron tubes.

Electron-Tube Generators.

One of the principal applications of the electron tube is as a generator of alternating current, particularly for radio frequencies. Advances in knowledge and control of their operation have been made. The reduction of harmonics is one problem which has been in considerable part solved. The characteristics of a number of French, British, and American tubes as power generators have been measured. A transmitting set employing electron tubes with alternating-current power supply was designed and constructed; it was used in experiments on fog signaling and other work. Two publications have been issued on this subject.

Two-Electron Tubes.

At the request of the Department of Justice a test was made of 50 tubes of the two-electrode type, to determine whether they could act as generators of alternating current. This question is of vital importance to users of electron tubes, the question being whether the older two-electrode tube can perform one of the important functions of the more recently invented three-electrode tube.

Power Rectifiers.

A great practical problem of radio telephony is the necessity for a power supply of relatively high direct voltage. One of the methods of securing such supply is the use of large rectifier tubes. A study of such tubes was made, including also the two accessory devices, the transformer system and the smoothing-out system. Ways were devised to increase the output by using three-electrode instead of two-electrode tubes as power rectifiers.

Electron-Tube Detectors.

A practical theory of detector action was worked out leading to the definition of detector coefficients. Methods of measuring the significant coefficients for any detector tube were worked out. Apparatus was designed and installed for measuring the input resistance and other important coefficients of detector tubes. Publications were prepared on the operation of an electron tube as an amplifying rectifier and on the measurement of detection coefficients.

Amplifiers.

Experimental amplifiers of novel types were constructed and measurements made upon them. Assistance was given other Government agencies in the choice and construction of amplifiers, and both laboratory and field tests were made. Experiments were made on the use of a small electron tube as a relay in a block signal device for safety of railroad trains at the request of the Bureau of Safety of the Interstate Commerce Commission. A scientific paper was issued on the dependence of the input impedance of a tube upon the load in

the plate circuit. Methods were developed for measuring the important properties of amplifiers as well as their parts, such as transformers, telephone receivers, and tubes. Permanent testing circuits were installed for measurements on audio-frequency amplifiers. Data were accumulated on typical amplifiers.

Radiotelephony.

The principles of radio telephony have been studied in the laboratory and a number of contributions of specialized character have been made to the improvement of this method of communication. A modern radio telephone transmitting set utilizes electron tubes, which perform the double duty of producing continuous waves at ultra-audible frequencies and also altering or modulating the intensity of these waves in accordance with the wave form of the sound. A theoretical and experimental study was made of modulation, using the oscillograph. This work has important applications to high-frequency wire telephony as well as radio telephony. The conditions were determined which limit the permissible values of the ratio of the carrier to modulating frequencies and thus the number of conversations that can be carried on simultaneously over a single system. A report was issued on the fundamental principles of radio telephony with electron tubes.

A proposed secret system of radio telephony was investigated. The experiments furnish a definite rejection of the proposed method but suggested other possible ways of attaining the desired end. No opportunity has been afforded, however, of pursuing this work further.

The theory of resonance circuits was worked out, particularly for electron tube generating systems. The principles of resonance filters for eliminating ripples and output current were developed. A brief study was made of three-phase power supply to eliminate the need of rectifiers for high-power telephone sets, with particular attention to circuits for smoothing out pulsations of the output current. Circuits were designed for eliminating the harmonics of high-frequency current. Contributions were made to the principles of design of audio-frequency choke coils and efficiency of other parts of the modulating circuits of radio telephone transmitting sets.

A research was completed on the principles and uses of large electron tubes, with only alternating current as the power supply. This involved building a radio telephone set, using four large power tubes, two as power amplifiers and two as rectifiers. Reports were sent to the Navy Department, for whom the work was done. Assistance was given a Navy experimenter in the design of a simple radio telephone set using 60-cycle power supply. A 100-watt telephone set was designed and built for laboratory, experimental, demonstration, and transmission work. A report was prepared upon this set.

A number of demonstrations of the radio telephone were given at the Bureau. In connection with this some important experiments in the wireless transmitting of music were made. With one form of apparatus the music is not heard at all at the transmitting station, but becomes audible at any other place within several hundred miles by the use of a radio-receiving set. Information was furnished a

large number of inquirers, including various manufacturers, electric-power companies, and the Forest Service, on radio telephone circuits, calculations, and methods.

Insulating Materials.

The work on the properties of insulating materials has as its objects improving the design of electrical apparatus, particularly for radio uses; reduction of power loss of electrical instruments; improvement of condensers for telephone and power uses; specifications for insulating materials for electrical purposes and applications to various mechanical and industrial uses; and improvement of commercial insulating materials.

Phenolic Materials.

Measurements were made of the mechanical and electrical properties of a large number of samples of phenolic insulating materials in the pure, laminated, and molded forms. This material has as its base a varnish which is either bakelite, redmanol, or condensite. Comprehensive tests were made on the machining qualities of the materials. A research has been in progress on the effects of moisture, weather, and time. Bimonthly measurements on certain samples have shown changes as great as 40 per cent in electrical properties. It has been found that considerable variations in the material occur as furnished at different times by some of the manufacturers. One result of the work has been that some improvements have been made in the material by manufacturers.

Miscellaneous Materials.

Measurements of the power loss at radio frequencies and other properties were made on glass, mica, micanite, asbestos, electrose, celluloid, wood, marble, hard rubber, fiber, paper, electrasote, resins, halowax, and paraffin. Data furnished by various manufacturers were compiled. A comprehensive comparative table of the properties of hard rubber, fiber, and phenolic materials was prepared. Among the interesting results of experiment were variations of the power loss with frequency; this furnishes data of value in research upon the theory of dielectrics.

Apparatus for Measurements Upon Insulating Materials.

Improvements were made in the apparatus used for measuring radio properties of insulating materials. These included improvement of the high-voltage storage battery used in generating circuits, additions to the high-frequency resistance standards, additional capacity screening and shielding, the extension of the frequency range, and the extension of the range of resistance or power loss measurable by using a perfect condenser in parallel with the test sample. Descriptions were prepared of the methods of measuring all the important electrical and mechanical properties.

Radio Measurements.

Instruments were standardized for manufacturers, industrial research laboratories, universities, engineers, and amateurs including wavemeters and decremeters, condensers and coils, electron tubes,

and ammeters. The radio measurements work included also research on methods of measurements and the improvement of radio apparatus, development and improvement of laboratory standards, and the giving of information on many kinds of radio measurements and instruments.

Standards.

The basis of capacity measurement has been more accurately established by measurements upon 10 condensers by the low-frequency absolute method, with extensive intercomparisons at both high and low frequencies. A new design of standard condenser has been completed which makes a great advance in the reduction of resistance, the great effects of very small pieces of solid dielectric having been eliminated. The basis of wave-length measurement has been improved, the laboratory circuits being intercompared and wave-length values established by stepping up to radio from audible frequencies by means of electron-tube harmonies. Measurements have been made on a remarkable new type of wavemeter consisting essentially of a quartz crystal.

Oscillograph.

Improvements were made in the cathode-ray oscillograph; hot and cold cathode types of tubes were compared. The principles of design were worked out and a publication issued. The device was applied to measurements upon quenched-spark transmitting sets, electron-tube transmitting sets, and the study of harmonics in electron-tube generators. Low-frequency oscillographs were used for radio telephone research, study of telephone receivers, and comparative wave form of signals.

Inductance Coils.

Methods of measurement were developed, formulas for coil calculation and design, and graphical methods of computation worked out. Theoretical formulas for capacity of coils were developed. Measurements were made on inductance, capacity, and resistance of inductance coils, in particular some coils of a new design with low capacity. A report was prepared on the extensive measurements that have been made on the inductance, capacity, and resistance of inductance coils.

Telephone Receivers.

Measurements were made to establish a standard audible signal for the testing of telephone receivers for radio use. Measurements of just audible current were made by a number of observers. The condenser transmitter was developed as an artificial ear, and the thermophone as a standard source of sound. Measurements were made of the sensitivity of telephone receivers for frequencies from 300 to 1,500. Measurements of the impedance at audio and radio frequencies were begun.

Miscellaneous Measurements.

The measurement of very small alternating currents by the use of a current transformer was investigated and a report prepared. Improved thermoelements for measuring small radio currents were

constructed. Measurements were made on the effect of type of modulation on continuous-wave currents, for the current not modulated, and for the current with sine-wave modulation and with rectangular-wave modulation. Contributions were made to the theory of parallel resonance of coupled circuits. Improvements were made in methods of shielding radio circuits. It is now possible to protect a measuring circuit from spurious effects regardless of the position of the observer or conditions in the generating apparatus.

RADIO ENGINEERING.

Radio Direction Finder.

Although the development of the radio direction finder or radio compass, as it is sometimes called, was undertaken by the Bureau before the war, its use for purposes other than military was delayed until after the cessation of hostilities. As a result of the Bureau's early work in this field, the Navy Department has established a large number of radio compass stations along the Atlantic and Pacific coasts. These stations are arranged in groups of three or more near the entrances of important harbors, and bearings are given, upon request, to approaching ships.

Recent experiments conducted by the Bureau in cooperation with the Bureau of Lighthouses show that the direction finder may be used effectively on shipboard. Radio bearings may be taken on radio stations on shore or on board ship and observations made directly by the navigator. A complete direction finder equipment has been installed on the lighthouse tender *Tulip*, which will serve to thoroughly test the practicability of the device as used on shipboard.

One of the most important applications of radio lies in its use in the navigation of ships and aircraft. The further development of the direction finder will materially aid in the solution of the important problems which are already well in hand.

Radio Fog Signaling.

The establishment and maintenance of aids to navigation are important functions of the Department of Commerce. In cooperation with the Bureau of Lighthouses, the Bureau of Standards has developed and made practical tests of a radio fog signaling system which promises to be of great assistance to navigation in time of fog or thick weather when light beacons no longer serve their purpose.

The results of a series of experiments conducted under practical conditions have led to the establishment of three permanent radio fog signaling stations or radio beacons, one on the Fire Island Lightship, another on the Ambrose Channel Lightship, and the third at the Sea Girt Lighthouse. These stations automatically transmit characteristic signal letters at frequent intervals during fog, and ships equipped with direction finders, or so-called radio compasses, can at any time take radio bearings on these stations, the locations of which are accurately known.

Unidirectional Radio Reception and Transmission.

The increasing use of radio communication for commercial, navigational, and military purposes, and the fact that the available channels of communication in the ether are limited, make necessary the

development of every possible means of utilizing these channels to the best advantage and with the minimum amount of interference.

A considerable part of the radio engineering work of the Bureau during the past year has been taken up in the study of this general problem, and particular attention has been given to the development of simple means of unidirectional reception and transmission. The method of unidirectional reception has been applied to direction finding with the result that the sense as well as the line of direction is obtained in a simple manner.

Radio Legislation.

The United States laws governing radio communication are enforced by the Department of Commerce through the Bureau of Navigation. The radio laboratory of the Bureau is called upon from time to time to cooperate with the Bureau of Navigation in many technical matters which arise in connection with this work.

On account of the rapid development of radio communication during the war, the present international and national laws which govern radio communication are inadequate and out of date. The Bureau of Standards, together with the Bureau of Navigation, has made a general study of the technical requirements of future legislation, and through a committee appointed by the Secretary of Commerce and representing all radio interests of this country, a comprehensive report has been prepared which forms an excellent basis for future legislation.

ELECTROLYSIS PREVENTION.

Electrolysis Problem Among Public Utilities.

The majority of the street railways of the country are operated on the single overhead-trolley plan, with the electric current flowing into the rails through the car wheels after it has passed through the car motors. The current then flows back to the generating station or substation by way of the tracks and earth, some of it, however, often flowing through underground gas and water pipes and the lead sheaths of underground telephone and electric-light cables, and sometimes through reinforced-concrete structures. The earth conducts electricity by virtue of its moisture and the salts dissolved in it, which render it an electrolyte. Hence, when the electric current flows away from iron pipes or lead cable sheaths, it carries away iron or lead by electrolytic action, and this in time may seriously corrode the pipes and shorten their useful life, sometimes completely destroying them in a relatively short time. The property damage caused by these earth currents when they are considerable affects to a greater or less degree all the public utilities.

The trouble is the more serious in places where the soil has a greater conductivity than usual and where the conductance of the tracks is small in proportion to the current, and the distance the current travels back to the stations is relatively great. Many remedies have been proposed and tried, but no standard practice for the handling of the return current has ever been agreed upon in this country. As the electric railways have been extended and traffic has become heavier, the volume of current handled has increased very

greatly, and the resulting destructive effects, which are cumulative with time, have become increasingly evident. In some cases litigation has resulted between the pipe-owning companies suffering damage and the railway companies whose current causes the trouble. But, although the courts have considered the question of legal responsibility, these cases did very little to prevent the trouble in an effective and economical manner.

Economic Importance of the Electrolysis Problem.

The subject of electrolysis of underground pipes, cables, and other metal structures is one which has been given more attention in recent years than formerly, but it still does not receive the attention in many quarters that its importance deserves. When one considers the enormous value of the pipe and cable properties buried in the streets of cities and forming in many cases transmission networks between cities throughout the country, and considers further that there are very few water, gas, or lead-cable systems which are not more or less subject at some points to electrolytic damage from stray currents, it is possible to form a better judgment of the practical importance of this subject. The water and gas pipe systems of this country alone have an aggregate value at the present time in excess of a billion dollars, and, in addition to this, there is a vast extent of underground lead-cable systems belonging to telephone and electric-power companies and to municipalities. There are also possibilities of trouble in the case of bridge structures, portions of steel-frame buildings, and piers, which are occasionally exposed to damage from this source.

While the total losses due to shortening the life of underground pipes and cables must be considerable, such loss does not by any means represent the total annual damage due directly to electrolysis. It is well known that the annual loss due to leakage of water and gas from distribution systems is very great. It is true that only a part, and probably a small part, of the total leakage is due solely to electrolysis; but it is only necessary to assume that a few per cent of the total is due to the more rapid development of leaks caused by electrolysis in order to make the total loss resulting from this cause run well into the millions annually.

Inconvenience and Hazard Due to Electrolysis.

It is not alone the property loss, however, that makes the electrolysis problem one of importance. An important fact is the inconvenience to consumers of water, gas, and telephone service due to the interruption of the service when repairs are made necessary by electrolytic damage. Possible interruption of the service of police and fire alarm systems is also one of considerable importance to almost every municipality.

Wherever currents are permitted to flow on the underground pipe systems there is the possibility of electric arcs being formed when pipes are disconnected or when different pipe systems make momentary contact. Accidents of this kind are rare, but they have sometimes occurred, resulting in the loss of life and a considerable damage to property. Cases have occurred also in which leakage of gas resulting from electrolytic corrosion of the pipe has given rise to

explosion with disastrous results. Many gas explosions in basements and manholes have occurred, and, although it is difficult to determine what proportion is due to electrolysis, undoubtedly some of them are due to this cause.

A water-pipe line weakened by electrolytic corrosion may even present a fire hazard much greater than would result from interruption of water supply at normal times. In many cities it is quite common practice during bad fires to increase temporarily the water pressure in the district adjacent to the fire. It is very obvious that a badly corroded water main might be capable of withstanding the normal pressure on the system and thus give no warning of the weakened condition of the pipe, but at the critical juncture during a bad fire, when the pressure is suddenly increased, the pipe may burst and thus seriously hamper the work of fire fighting. It will readily be appreciated that in any region in which electrolysis damage is in progress to a greater or less extent the mains are far more likely to break at these critical times than at any other period, and thus a real, though indirect, fire and life hazard due to electrolysis must be recognized.

Electrolysis Mitigation and Related Problems.

In the field of electrolysis mitigation the Bureau's work has been considerably curtailed for a number of years. During the war it was practically suspended, and since that time funds have not been sufficient to put it on a normal basis. However, a number of important investigations have been carried on during the past year.

Development of Apparatus for Making Electrolysis Surveys.

Throughout the first half of the year the time of one man of the section was devoted largely to development work on improved methods and apparatus for electrolysis testing. Several modified forms of apparatus for measuring current flow in pipes and leakage current from pipes were developed and experimented with in a preliminary way in the laboratory and some were used in actual field work. The apparatus for making rapid surveys of current flow in pipes from measurements made on the surface was completed and made ready for field use. The other apparatus was not completed because of the pressure of other work, and it is hoped to take them up and complete them some time during the coming year.

Corrosion of Lead.

A considerable amount of work was done on the electrolytic corrosion of lead. This work was rendered necessary by the fact that the previously published work of the Bureau on this subject had been called seriously into question by engineers representing the principal cable interests, so that further work was necessary in order to resolve questions in dispute. The earlier work of the Bureau had indicated first that the coefficient of corrosion of lead with ordinary direct current was considerably less than unity, the actual corrosion being in general only about 25 to 30 per cent of the theoretical amount, and, second, that under periodically reversed currents of a period not exceeding 10 or 15 minutes the corrosion of lead was substantially negligible.

Extensive investigations of both subjects were carried out in close cooperation with engineers of the cable interests who had taken exception to the previously published reports. The result of the investigation was to establish to the satisfaction of the interests concerned the correctness of the results previously obtained and published by the Bureau. Some additional important information was obtained with reference to the effect of moisture on the coefficient of corrosion of lead with direct currents. The investigation revealed the fact that in the case of lead, as had previously been shown to be true in the case of iron, the coefficient of corrosion is largely influenced by the moisture content of the soil in which corrosion takes place, the drier the soil the lower being the coefficient of corrosion. This investigation has placed on a definite basis the electrolytic corrosion of lead under known conditions.

Investigation of Lead Cable Troubles in St. Louis.

Early in the year there was brought to the attention of the Bureau for the second time what appeared to be a very unusual case of lead cable failure on the high tension underground mains of the Union Electric Co. in St. Louis, and the Bureau was urged to investigate the trouble. In view of the fact that it appeared not improbable that electrolysis might be an important factor in the trouble, the investigation was undertaken by the electrolysis section. This investigation was pursued as opportunity afforded, and during the winter a detailed report was submitted to the Union Electric Co. and other interested companies in St. Louis, in which the various causes of the failure were fully discussed. The results of the Bureau's investigations have been accepted by the Union Electric Co., but in view of the fact that the conclusion was reached that one of the principal causes of the corrosion was the very bad electrolysis condition which existed for some time after the cable system was installed in 1913, thereby placing a large amount of responsibility on the railway company, the railway company has not as yet indicated its willingness to accept the conclusions without question. The railway company is endeavoring to show that the use of fiber conduit was a more important factor than the investigations of the Bureau indicated. In order to answer this objection more completely, the Bureau is at present gathering information as to the experience of other companies that have been extensive users of fiber conduit for a period of years. It is expected that this additional information will be at hand within the next two months, after which a final report can be prepared bringing this investigation to a close.

Electrolysis Field Surveys.

Two important field surveys have been made by the Bureau during the period in question, one in Des Moines, Iowa, and the other in Springfield, Mass. The investigation in Springfield, Mass., was the resumption of the work done there several years ago and had for its object to determine whether the railway company should continue operating with the three-wire system or should revert to a two-wire system with suitable substations and insulated return feeders. The investigation indicated the latter to be the better solution of the electrolysis problem. A report has been submitted to the interests concerned, definitely recommending two-wire operation for Springfield.

The second investigation was conducted in Des Moines, Iowa, and had for its object to determine the effectiveness of the automatic substation in mitigating electrolysis. In a certain sense this investigation was a cooperative one with the research subcommittee of the American Committee on Electrolysis, but it was planned and executed by the Bureau in a manner very similar to previous electrolysis surveys made in other cities.

Cooperation with the American Committee on Electrolysis.

Early in the year definite arrangements were made with the American Committee on Electrolysis, which represents all of the great national associations of utility companies, for cooperative work between that committee and the Bureau in conducting an extensive research in the field of electrolysis mitigation. After this arrangement had been made the committee asked the Bureau to outline a program of research work to be carried out jointly, and such a program was formulated by the Bureau and approved by the committee. During the last four months a number of somewhat extended investigations have been carried out in coöperation with this committee in a number of cities in the Middle West. This work has been confined almost exclusively to the effect of pipe drainage on underground systems, especial attention being given to the possibility of joint electrolysis on high-resistance joints and interchange of current between drained systems. Some attention has also been given to the three-wire systems of power distribution and also to automatic substation installations as a means of electrolysis mitigation. This joint investigation is an extremely important one, and it is hoped that means will be found for continuing it during the coming year, although it now seems necessary to curtail the work for a time on account of lack of funds.

SAFETY ENGINEERING AND SAFETY STANDARDS.

National Electrical Safety Code.

The Bureau has been engaged for seven years in a study of the life hazard in electrical practice and in the preparation and application of the National Electrical Safety Code. In this work it has had the cooperation and assistance of a large number of engineers, many of whom are connected with the electrical operating and manufacturing companies, others being engineers and inspectors of State commissions, municipalities, and insurance underwriters. The various national associations connected with the electrical industry have also cooperated effectively in this work. The importance of having a national code uniform in all the States is generally realized, and also the advantage of having such a code prepared and presented by a national agency that can study the subject thoroughly and consult all the interests affected.

The safety code consists of four principal parts, as follows:

1. Rules for the installation and maintenance of machinery, switchboards, and wire in central stations and substations.

2. Rules for the construction and maintenance of overhead and underground lines for the transmission and distribution of electrical energy and intelligence.

3. Rules for the installation and maintenance of electrical apparatus and wiring in factories, residences, and wherever electricity is utilized for light, heat, or power.

4. Rules to be observed by operators in working on or near electrical machines or lines.

The code is intended to be adopted by State industrial and public-service commissions and municipalities and to be complied with by public-service and industrial corporations. It is also intended to be adopted voluntarily by electrical interests when the code has not been adopted by any administrative body having jurisdiction in their district.

The Bureau's thorough study of the diverse conditions under which electricity is generated, distributed, and utilized, and of the effect of the rules on operating and construction costs, has secured a code which involves no unreasonable expense, but in general assures an adequate measure of safety and a useful standardization of practice. The large number of conferences held in all parts of the country for discussion of preliminary drafts of the code aided largely in its development. The varying conditions in different geographical sections and in thickly and thinly populated districts have been given careful attention.

The code was published originally in two installments for examination and criticism; the operating rules were published in August, 1914, and revised in May, 1915; the construction rules were published in April, 1915. Both operating and construction rules, again revised after a general conference of all interests in Chicago in the spring of 1916, were combined in a single volume, Circular No. 54, which was published in November, 1916, with a recommendation for actual field trial.

It has been the intent of the Bureau, as well as the desire of all branches of the industry, that the rules should be revised and extended as experience in their use and the progress of the electrical industry shows revision and amplification to be to the public advantage.

The last edition has now been revised and copy is ready for reprinting. It is proposed to issue the new edition in pocketbook size and to segregate the discussion under a separate cover from the text of the rules. A pictorial edition of the rules, showing their application by illustrations, and a volume of engineering data, are also planned and have been partially prepared.

Engineering Work in Connection with the Safety Code.

Considerable work has been done on engineering data for the construction of outdoor electrical lines, especially with reference to poles and steel towers for supporting overhead conductors and to the sags of the conductors so supported. Sags have been computed for temperatures other than those used in the original published tables, and steel wires and cables have also been included.

National Electrical Safety Code in Practical Use.

The code has now been adopted in one form or another, in part or in whole, by some 20 administrative bodies, and many others have taken favorable action upon it, such as the issuance of bulletins

recommending the application of the code. In a few States its application has been made mandatory, notably in Pennsylvania, Wisconsin, and Montana. The code is also being used as a basis for a merit-rating schedule by casualty insurance interests. Such schedule rating should result in emphasizing both the merits and demerits of particular installations from the safety standpoint and tend to reduce accidents by proper financial recognition of each improvement made.

The code is also being voluntarily applied by a large number of utilities and industrial concerns in their own practice. It is becoming generally understood that the stability in electrical practice provided by such a national standard conduces greatly to general economy and safety.

Industrial Safety Standards.

As a result of the work on the National Electrical Safety Code and the numerous points of contact thus established with State authorities and others interested in safety work the Bureau has been called upon to enlarge the scope of this work and to consider safety requirements in other than the electrical industry.

In order to arrange for more complete cooperation in this work and to insure the coordination of the efforts of all parties concerned, a conference was held at the Bureau on January 15, 1919, which was attended by more than 100 representatives of different organizations concerned with safety standards.

On December 8, 1919, another conference on industrial safety codes was held at the Bureau and was attended by representatives of all interests from many parts of the country. The conference voted in favor of having safety codes prepared under the auspices of the American Engineering Standards Committee. It also provided for the formation of a joint safety code committee to prepare a list of codes already in existence or urgently needed, and to recommend sponsors for preparing and revising these codes. Such a committee was organized by the National Safety Council, the International Association of Industrial Accident Boards and Commissions and the Bureau of Standards. This committee is now known as the National Safety Code Committee. It has held three meetings and has reported to the American Engineering Standards Committee a list of codes and recommended sponsors. Most of the recommendations have been approved by the American Engineering Standards Committee. The codes recommended for sponsorship by the Bureau of Standards are the following:

National Electrical Safety Code.
National Gas Safety Code (joint sponsorship with the American Gas Association).
National Safety Code for the Protection of Head and Eyes of Industrial Workers.
Combined Electrical Fire and Safety Code (joint sponsorship with the National Fire Protection Association).
National Safety Code for Protection against Lightning (joint sponsorship with the American Institute of Electrical Engineers).
National Safety Code for Logging and Sawmill Operations.
National Safety Code for Aeronautics.

All of these but the latter have been approved by the American Engineering Standards Committee.

Heads and Eyes Code.

Two successive drafts of the Safety Code for Heads and Eyes Protection were prepared during the year and circulated for comment. On March 12 a meeting was held in Philadelphia by the advisory committee which had been organized for this code and most of the questionable points were settled. The remaining points have since been disposed of and a final draft of the code prepared for printing. A discussion to accompany this code has also been prepared.

Logging and Sawmill Code.

A rough draft of this safety code was prepared from a study of existing requirements and our general knowledge of such operations. Field inspections were made by members of the staff in the Virginia woods and later in the South as far as Louisiana, and in New York State and New England. As a result of these field inspections and comments by the Bureau's staff a revised draft of this code will be circulated for wider comment.

GAS ENGINEERING.

Standards for Gas Service.

The increasing difficulty of obtaining oil and other gas-making materials, and of financing improvements and replacements of gas plants, has given rise to a critical situation in the gas industry. During the year the Bureau has received an unusual number of requests for assistance from cities which were dissatisfied with their gas service, and advice has been sought in other cases where, as a means of reducing costs of manufacture, gas companies have appealed for a reduction from the high standards of quality which have hitherto prevailed in this country. Such readjustments of standards to meet changed conditions are economically desirable and in this case practically inevitable, but the effects of such changes are manifold, and some of them are difficult to foretell. For example, it is as yet uncertain to what extent the amount of gas used by the average customer would be affected by a given reduction in the heating value of the gas supplied. It is certain that many of the arguments advanced regarding the relative usefulness of gases of different quality have been based on exceedingly meager engineering or experimental data. It is also certain that the usefulness of any gas must depend on the proper design and adjustment of the appliances in which it is burned. Consequently such experimental work on gases as the Bureau has been able to do during the past few years has been directed to these two ends: that is, to furnish a better foundation of definite knowledge regarding the usefulness of different gases, on which a fair readjustment of standards may be based, and to improve the design and promote the proper adjustment and maintenance of gas appliances in common use.

In such unsettled conditions as now exist in the gas industry, when both operating companies and regulatory authorities have to meet new problems and make decisions based at best on a very limited fund of experience, the services of the Bureau as a clearing house of information are especially valuable. Its contact with interests of every kind in all parts of the country enables it to apply to any particular local problem the results of experience in other places,

and thus to save much duplication of effort and of costly experimentation by local authorities who otherwise would have no means of knowing current developments elsewhere. Moreover, the Bureau's established position as an impartial agency has frequently made it possible to improve the relations between the companies, the authorities, and the public, thus opening the way for cooperative effort in meeting the difficulties which have arisen.

In order to strengthen its connections with all interests concerned, and to make its services of the greatest possible value to all, the Bureau has formed during the year a consulting committee of gas engineers, including representatives of State commissions and of gas companies, as well as independent consulting engineers. In the revision of Circular 32, "Standards for Gas Service," which has been under way during the year, the Bureau has profited greatly by the hearty cooperation of this committee. The tentative manuscript of the new (fourth) edition was mimeographed and sent out for study and criticism: after a preliminary revision based on written comments was made, the committee met at the Bureau on January 13 and 14, 1920, and discussed fully the outstanding points on which there were differences of opinion. Although this procedure can not be expected to bring about complete unanimity, it will give this circular an authority even greater than that which it has previously had, and is a long step toward the solution of public-service problems on the basis of reasonable economic and engineering considerations rather than by bitter political or legal fights.

The new edition of Circular 32 is now in press, and a separate circular, giving a revised collection of current rules and laws governing gas service, will be ready for the printer as soon as copies of some very recent State rules are received.

Gas-Service Inspections.

While advice and information have been given by correspondence to authorities in all parts of the country, the limited amount of field inspection work which could be done has been confined almost entirely to the southeastern section. The Bureau has had frequent calls, especially from the State commissions of Maryland, Virginia, North Carolina, Georgia, and Alabama. More or less complete inspections have been made of the gas plants, and the service furnished in Annapolis, Cambridge, Crisfield, Cumberland, Easton, Elkton, Frederick, Salisbury, and Westminster, Md.; Anniston, Birmingham, Decatur, Gadsden, Huntsville, Mobile, Montgomery, and Selma, Ala.; Athens, Ga.; and Durham, N. C. Reports on these inspections have in general been made to the respective State commissions. In some of these places the Bureau has been able to show how conditions might readily be improved to the advantage of all concerned: in others it could only corroborate the claims of the gas companies that they were doing all that could reasonably be expected under the difficult circumstances then existing. Even this assurance from a disinterested party has, however, some value in such cases in that it helps to create a better feeling and to facilitate arrangements which may be necessary in order to improve the service. In all this work care has been exercised not to encroach on the proper field of activity of private consulting engineers, and in cases where rebuilding or alterations of plant appeared to be desirable the Bureau has given

only general advice, referring the companies to reputable engineers for detailed studies and estimates.

Gas-Appliance Investigations.

The investigation of gas-burner design and operation, begun last year in cooperation with the industrial fuel committee of the American Gas Association, has been continued actively throughout the year. This work is an essential preliminary of the investigations which have been in mind for several years, looking toward improvement in the efficiency of use of gas. The proper design of air shutter, gas orifice and burner throat to give the maximum injection of air under the ordinary conditions of use of gas was the part of the problem particularly assigned to the Bureau. Some months were spent in designing and developing suitable apparatus for making the necessary measurements of the air and gas, but the equipment developed has proved so satisfactory that results have been obtained rapidly on experimental burners representing a wide variation in the dimensions which have to be considered in the design of burners. An extended report of the results so far obtained was presented to the industrial fuel committee in June.

The work covered in this report was done primarily with reference to industrial burners, but the urgent need for conservation of natural gas and for improvement in natural gas service as supplied to households suggested the desirability of extending this investigation to the types of domestic burners used with that gas. Since transportation of sufficient quantities of gas to Washington was not practicable, the Bureau of Mines provided space in its Pittsburgh experiment station, and late in the year experiments were begun there to find what range of efficiency is actually obtained in the use of natural gas and what degree of improvement is practicable. This work has already progressed far enough to show that many appliances as used are very low in efficiency and that great improvement in this respect can readily be made. Specific tests, for example, have shown that equipment which now makes use of only 10 to 30 per cent of the heat of the gas can be made to use 30 to 50 per cent. Such increases in efficiency, if generally obtained, would be equivalent to doubling the supply of gas available.

Results of great importance have also been obtained in the design of natural gas burners to operate on low pressures. It is a common experience that in very cold weather the gas pressure falls for various reasons so that the usual gas appliances become practically useless. This investigation has shown that burners can be so designed as to operate well on natural gas at low pressures such as are used with manufactured gas; and it is possible that an improvement in service might be made by installing regulators which would supply gas at a low and uniform pressure. The adoption of this plan, however, would require considerable changes in gas distribution systems valued at many millions of dollars, and before it could be definitely recommended extensive engineering studies would be required.

National Gas Safety Code.

As indicated in last year's report, work on the Gas Safety Code has been necessarily deferred because of lack of adequate support for the gas-engineering work. Some progress has, nevertheless, been

made during the year. Technologic Paper No. 133, "Tests of Flexible Gas Tubing," prepared last year, was issued in October. Part 3 of the code, on gas fitting, has been practically completed, and the Committee on Gases of the National Fire Protection Association has already adopted it with very few changes as the association's rules for house piping. Part 2 on distribution, is ready for discussion and has been submitted to the American Gas Association for criticism. The first draft of Part 1, on manufacture, has been completed, and will be prepared as soon as possible for submission to outside engineers.

In initiating this work the desire of the Bureau was to serve as a coordinating agency in order that the resulting code might be adequate for the protection of gas-company employees and customers and of casualty and fire-insurance interests, and at the same time be acceptable to the gas companies and the gas-appliance manufacturing and selling interests. Since the work was undertaken systematic provision for such cooperative work has been made through the reorganization and enlargement of the American Engineering Standards Committee, which has assigned the sponsorship of the Gas Safety Code jointly to the Bureau and the American Gas Association.

Avoidable accidents, due to ignorance or carelessness in the use of gas or to faulty installation, result in hundreds of deaths and the loss of large amounts of property every year. If the code could be completed and adopted throughout the country an important reduction in these losses could reasonably be expected, both because of the official enforcement of the code and because of its educational value to gas fitters, appliance manufacturers, utility operators, and the general public. The code would also encourage uniformity of practice in gas installations and gas-company operation throughout the country and such uniformity would contribute to efficiency and economy in construction, operation, and maintenance. It is therefore desirable from every point of view that the code be completed and issued as soon as is practicable, and the Bureau regrets exceedingly that there is no prospect of its being able to supply an adequate staff for the work during the coming year.

ELECTRICAL AND OTHER SERVICE STANDARDS.

Standards for Electric Service.

For several years the Bureau has been studying the question of specifications for electric light and power service, and the requirements that should be made by municipalities or by State public-service commissions of the public-utility corporations engaged in furnishing such service. This study was published in 1916 as Circular No. 56, "Standards for Electric Service," and is now out of print.

In addition to proposed State rules and specifications for acceptance of types of meters, the circular contains three regulatory ordinances, suggested for cities of various sizes, descriptions of commissions' standardizing laboratories, and a complete and exhaustive digest of State rules and of ordinances in force in various cities. The demand for this circular has been large, and it is gratifying to note that the rules, specifications, and ordinances proposed have been made the basis for State rules and city ordinances in many instances.

Even before the circular was published a few States had revised their electric-service rules, and an appendix was added to include the new material. Since its publication at least six new commissions have been established, the functions of several old commissions have been radically changed, and service rules have been revised in a number of States. The new laws and revised rules have been collected and are ready for inclusion in a new edition of the circular. The material has been rearranged and much new matter is included. The new edition will be an exhaustive summary of present-day electric-service regulation.

In all this work the Bureau has profited by the cordial cooperation of public-service commissions, municipalities, and public-service corporations, the National Electric Light Association, and the Association of Edison Illuminating Companies.

Standards for Street-Lighting Service.

For more than a year before the war the Bureau was engaged in a study of street lighting in its technical and engineering aspects, with particular reference to the requirements that should be put into contracts between municipalities and public-service corporations for furnishing gas and electric street lighting. A number of municipal and private plants were inspected, photometric measurements made, and conferences held with managers and illuminating engineers.

The Bureau was receiving the hearty cooperation of municipalities and lighting companies, but the war necessitated discontinuance of the work.

During the year the work was again taken up in order to keep in touch with street-lighting developments. New contracts have been added to our files and the analysis of contracts continued. The manuscript for a circular on "Standards for Street-Lighting Service" is partly completed.

As in the case of Standards for Electric Service, the Bureau seeks, while representing the public, to get the utilities' point of view as well; the study of street lighting is being continued, but the result will not be published until full discussion and cooperation can be again secured from public-utility corporations, technical societies, municipalities and city managers and other interested parties.

Standards for Heating Service.

At the request of the Public Service Commission of Indiana a study of standards for central-station hot-water heating service was begun in 1918. Field investigations were made in Ohio, Indiana, and Illinois, heating plants visited, and conferences held with operating engineers. The cordial cooperation of the educational committee of the National District Heating Association has been of much value.

A proposed set of rules for the regulation of central hot-water heating plants was formulated and submitted to the Indiana commission and, after public hearing and criticism, was made the basis for the rules formally adopted by that commission. The Bureau has now nearly completed the manuscript of a circular on central-station heating. This contains summaries of regulations, so far

adopted by States, for both steam and hot-water systems, and proposed rules and regulations for commission adoption. Methods for calculating "radiation," that is, customers' heating requirements, engineering phases of contracts with customers, and brief suggested contracts, are included in the study. It is hoped to complete this circular during the next fiscal year with the cooperation of the special committee of the National District Heating Association and other associations and engineers interested in central-station heating problems.

Engineering Standardization.

The Department of Commerce is a member body in the American Engineering Standards Committee, three representatives of the Bureau of Standards being members of the committee. At the request of the standards committee the Bureau has prepared a complete list of engineering and technical organizations engaged in or interested in engineering standardization. More than 150 societies and organizations have cooperated in the preparation of this list, and many requests for copies have already been received from Government departments and engineering organizations. It will be published early in the next fiscal year.

TELEPHONY.

Studies of Systems of Telephony.

Considerable progress has been made in the detail study of telephone systems, work on which was begun two years ago as a necessary preliminary to an intelligent study of the broader subject of telephone service. Particular attention has been given to the newer types of cord circuits of the Kellogg Switchboard & Supply Co. and the Stromberg-Carlson Electric Co. and to the machine-switching systems of the Automatic Electric Co. To these might be added the machine-switching system of the Western Electric Co., a preliminary study of which was only begun in June. The need of labor-saving equipment, never so apparent as at present, has focused attention on the above systems, all of which are designed, among other things, to reduce operating labor.

In connection with our studies of circuit operation a departure from the conventional type of schematic diagram has been made. The new diagrams differ from the old in that associated contact springs, though properly identified, are shown separated from their actuating relay or magnet and are so placed as to emphasize their operative relation to the circuits which they control or operate. The component circuit elements are arranged so as to bring out as clearly as possible the mode and sequence of operation.

Circuit diagrams when so drawn may be considered as describing in a particular type of shorthand full detail of circuit operation. On this account it has been suggested that they be called "functionalized circuit diagrams."

Many circuits of manual, automatic, and semiautomatic switching equipment of all the leading types and makes have been redrawn in the manner described, thus making it possible to trace the circuit operation readily without the need of the peculiar type of memory re-

quired for equal familiarity with the corresponding conventional schematics.

The diagrams have also proved of great value in the preparation of descriptions of circuit operations, which necessarily requires a clear understanding of each successive step. They will also be of value in connection with the diagnosis of "off-normal" and trouble conditions. Additional advantages of the "functionalized circuit diagrams" are found in connection with circuit analysis and with comparative studies of circuits of the same general type or of circuits differing in minor details.

Such diagrams should serve a very valuable purpose in connection with the training of the many telephone employees required to carry out the extensive automatic program announced by one of the largest operating organizations.

Telephone Circular.

The tentative draft of a proposed publication on "Telephone service," to appear as a Bureau circular, was completed late in the fiscal year. As suggested by the title, emphasis has been put on the subject of service, although a considerable part of the text has to do with practice.

The object of the publication is to describe telephone service in such a manner as to give the reader a fairly comprehensive understanding of what is involved in rendering telephone service and what the elements of the service are which determine its grade. Its scope is limited to a general introductory treatment of the subject suitable for those who desire only a brief discussion. A more detailed and more technical presentation is reserved for subsequent publications.

In order that the circular may be as accurate as possible and hence of maximum use when issued, mimeographed copies have been sent to representatives of the Bell and larger independent telephone companies, to most State commissions, and to a number of individuals for comment and criticism before final revision for the printer.

Another proposed telephone circular, the rough draft of which is nearing completion, has to do with telephone transmission. This paper, largely mathematical in character, takes up in order the subjects of the uniform line, composite lines, equivalent circuits, receiving-end impedance, fitting problems, artificial lines, and loading.

Laboratory Work.

Work in the telephone laboratory during the year was limited almost wholly to testing. The recent addition of an oscillograph and other apparatus, however, will permit the undertaking of additional tests as well as certain research work planned some time ago.

Tests made and under way include transmission and efficiency tests in connection with inquiries relating to repeating coils; tests of the loss in the efficiency of telephone receivers resulting from the use of spool heads of conducting materials; determinations of the electrical and mechanical characteristics of radio receivers of various manufacturers, and the testing of dry cells for use in local battery telephone systems. The latter test, just begun, will of necessity extend over the greater part of a year, since the test involves the determination of the variation with time of the resistance and electromotive force of the cells under conditions simulating those met with in service.

INVESTIGATION AND TESTING OF ELECTRIC BATTERIES.

New Testing Equipment.

Much new testing equipment has been put in operation during the past year for the purpose of increasing the accuracy of the tests, the range of temperatures at which tests can be made, and to reduce the labor involved in making the tests.

The automatic control apparatus for dry-cell testing has been completed. This apparatus carries on a number of different tests, as required by the different types of cells, simultaneously. It measures the periods of discharge and recuperation with great exactness. Only one man is now required to attend to this branch of the work, where formerly two or three men were necessary for the same number of batteries under test. A brief description of this apparatus has been prepared and is being published as Technologic Paper No. 171.

Apparatus has been installed for the testing of batteries at freezing temperatures and below. The capacity of all kinds of batteries is reduced at low temperatures and it is important to determine the operating characteristics of the different types of cells at low temperatures. Railroad signal cells for example are exposed to extremely low temperatures in certain States during the winter; storage batteries used on industrial tractors are often exposed to low temperatures; other types of storage batteries and dry cells are frequently subjected to low temperatures in airplanes. The equipment which has been installed consists of a refrigerated room cooled by a 2-horse power compressor that is automatically controlled by a thermostat in the room. The compressor runs intermittently and maintains a constant temperature within the room. The room was also designed for making the low temperature tests of caustic soda batteries specified by the signal division of the American Railway Association.

A Freas water thermostat has been installed for the determination of temperature coefficients of the various types of cells. This is intended for use at temperatures slightly above and below room temperature and it can be controlled to within 0.005° C. It is also used for fundamental measurements of electrochemistry.

A constant current discharge apparatus has been designed and installed to maintain the discharge current of railway signal batteries when on test at a fixed value day and night without requiring the attendance of the observer. This apparatus will maintain the current constant to within 1 per cent.

A new test rack for storage batteries of the starting and lighting type has been constructed. It is divided into six panels, each accommodating four batteries. Suitable resistances and switches have been provided for the charge or discharge of the batteries on test without requiring the batteries to be moved or the connections changed. In this way the labor of making such a test has been greatly reduced.

A vibration board for testing storage batteries has been constructed. The object is to test the mechanical construction of the batteries when subjected to severe vibration. A comparison of different makes of batteries indicates that some are much better fitted for hard service conditions than other.

Tests of Batteries.

Forty tests have been made for various Government departments on 217 batteries and three commercial tests on 17 batteries. These tests have been made for the Panama Canal, the Motor Transport Corps, the Signal Corps, and the Ordnance Department of the War Department. The batteries submitted for test have consisted of various sizes and kinds of dry cells, flashlight batteries, storage batteries, and railway signal batteries. In addition to these tests a large number of other tests of the performance of dry cells and storage batteries have been made to obtain information required in writing specifications and the preparation of circulars of information.

Dry Cells.

Measurements of the conductivity of powdered manganese ore and carbon have been continued and the study of the corrosion of zinc by solutions used in dry cells has been extended to include the effect of many impurities which are likely to be present in manganese ore.

The study of the effect of hydrogen ion concentration on the potential of the manganese dioxide electrode was continued, and Scientific Paper No. 364 on "The Relation of the Voltage of Dry Cells to the Hydrogen Ion Concentration" was published. This paper shows the effect of acids and alkalis in dry cells and the reasons that cells made of the same materials may differ in voltage.

An extended test has been made in various brands of dry cells to determine which are made with the artificial oxides and which with the manganese ore. Cells made with the artificial oxide may give a large output when they are new but deteriorate rapidly. It is therefore important to determine the material from which the cells are made.

A chemical investigation of the best methods for determining the presence of impurities in manganese ores has been carried out and the results summarized in the form of a manual for laboratory use.

Storage Batteries.

A careful series of measurements on the structure of vehicle type storage batteries of different manufacturers has been made. These measurements include the weights and dimensions of all parts, and the electrical breakdown, tensile strength, and elongation of the jar material. These measurements yielded much valuable information for the preparation of specifications.

The investigation of the cadium electrode mentioned in the previous report was completed and published as Technologic Paper No. 146, entitled "The Cadmium Electrode for Storage Battery Testing." The investigation of nitrates and nitrites in storage battery electrolyte was completed and published as Technologic Paper No. 149, "The Estimation of Nitrates and Nitrites in Battery Acid."

A large number of measurements have been made on the effect of temperature on the capacity of storage batteries, including both the acid and alikaline types. It is desirable that accurate information as to the temperature corrections for the different types of batteries and at different rates of discharge should be available to increase the accuracy of tests and decrease the time required to make them. A part of this work has been completed, but additional

investigations will be made in the low temperature room mentioned above.

A circular, No. 92, on vehicle type batteries has been completed. It is entitled "Care and Operation of Vehicle Type Batteries." This circular was prepared at the request of the Construction Division of the War Department as a guide for the use of batteries of this type in military depots. It is also intended to furnish information in answer to the questions contained in the manual of storage batteries issued by the committee on education and special training of the War Department. It includes a discussion of the fundamental principles of acid and alkaline storage batteries and gives typical performance curves for each under varying conditions; it discusses the capacity, the voltage, the resistance and the reactions of storage batteries; it describes the methods of charging and of testing; and it gives directions for the treatment of batteries in bad condition, for the dismantling and repair of acid batteries, and for storage batteries not in use. The appendixes contain the War Department specifications for batteries of this type and for battery charging equipment. Other appendixes give sample record forms for the proper operation of batteries and an outline of the method for computing costs of operation. The last appendix contains a glossary of more than 300 terms used in connection with storage batteries.

Specifications for starting and lighting batteries have been prepared, at the request of the Motor Transport Corps. The necessity for these arises from the magnitude of the industry and the fact that many batteries of inferior quality are now on the market. A conference of representatives of the Motor Transport Corps, the Bureau of Steam Engineering, Navy Department, the Society of Automotive Engineers, the manufacturers, and the Bureau of Standards was held at the Bureau to discuss them.

A series of experiments on the loss of capacity of acid and alkaline cells has been carried out. The object was to determine the rapidity with which cells of different types lose their charge when standing idle at a constant temperature. Another set of experiments has been made to determine the efficiency of storage batteries, particularly with reference to the rate at which the batteries are charged and discharged.

The preparation of a circular on starting and lighting batteries has been begun. This circular is intended to be brief, containing only the information of greatest use to the owners and operators of automobiles. It is to include a survey of the many sizes and kinds of batteries now on the market, the specifications as prepared for the Motor Transport Corps, and such data on the starting equipment as may be necessary for a proper understanding of the work the battery has to do. The number of different sizes and kinds of storage batteries for this purpose at present on the market is unnecessarily large, and the cost of production of these batteries could be considerably reduced by a proper standardization of the sizes with the elimination of a very large number which are little used.

The value of testing these batteries was emphasized by a recent test of samples for a large order. Tests showed them deficient electrically and mechanically. They were found to contain second-hand material.

Railway Signal Batteries.

These batteries are of the copper-oxide-zinc type with an electrolyte of sodium hydroxide. They are used for operating signals and similar equipment on many railway lines. During winter they are often subjected to very low temperatures which impair their performance. The Bureau has been called into consultation on this subject by both the manufacturers and the signal division of the American Railway Association. At the request of the latter, the Bureau has sent a representative to the meetings of the signal division and the battery committee. The Bureau has advised as to specifications and tests for this type of battery. The performance of these batteries in various typical installations of signals, crossing bells, track switches, and interlockings has been studied. It is planned to make a very thorough investigation of these batteries during the coming year, with the low-temperature apparatus described above.

Storage-Battery Nomenclature.

A representative of the Bureau was appointed a member of the committee on storage batteries of the American Institute of Electrical Engineers. At their request, the Bureau has prepared the definitions and nomenclature dealing with storage batteries. This has been adopted by the standards committee, with slight modifications, and is to be included in the new standardization rules. Up to the present time the definitions of capacity, final voltage, and standard temperature, etc., have differed widely among the various manufacturers. It is important, therefore, that these rules should set a standard with which the product of the various manufacturers may be accurately compared and tested.

Standard Cells.

On January 1, 1911, the Clark standard cell was officially superseded by the Weston normal cell as the international standard of electromotive force notwithstanding the fact that a number of investigators had held that the Clark cell was the more constant with time. One of the chief reasons for this action was the frequent failure of Clark cells through cracking of the amalgam limb about the sealed-in terminal wire, and through the formation of gas in the amalgam limb. The seriousness of these defects is shown by the fact that 90 per cent of the Clark cells set up at the Bureau in 1906 are to-day useless because of one or both of these faults. Other investigators had similar experiences.

Experimental work has shown that cracking of the Clark cell can be prevented by employing as the negative or amalgam terminal platinum wire subjected to the action of zinc amalgam before sealing it through the cell wall; also that the effects of gas formation can be minimized through the use of only enough crystals to insure saturation at the highest temperature at which the cell is likely to be used. A more detailed account of this investigation will shortly appear as Scientific Paper No. 390.

In order that we might obtain a reliable intercomparison of the standards of electromotive force of England, Japan, and the United States, four selected Weston normal cells were sent to the National

Physical Laboratory in England and a like number to the Electrotechnical Laboratory in Japan for comparison with the reference cells of those countries. The cells were selected because of their relative constancy over a long period and it is hoped that measurements to be made on their return to Washington will show them to have changed but little during their absence.

RADIOACTIVITY AND X-RAY MEASUREMENTS.

Gamma-Ray Measurements of Radium.

The amount of gamma-ray testing has increased so greatly and so rapidly that all other work of the section has had to give way to it. All investigations have been practically discontinued, requests for X-ray and luminous material tests have not been encouraged, and the few of these tests that were made have had to wait, often for months, until a lull occurred in the gamma-ray work. During the year over $24\frac{1}{4}$ grams of radium and mesothorium were received for test, while during the entire proceeding $5\frac{1}{2}$ years a little less than $32\frac{1}{2}$ grams were received. All indications point to a further increase in the demand for this work.

The increase during the six and one-half years since routine testing of radium was begun is shown in the following table:

Year.	Number of tests.	Milligrams of radium.	Year.	Number of tests.	Milligrams of radium.
1914 (half year)	28	486	1917–18	1,248	5,376
1914–15	98	2,097	1918–19	1,068	13,367
1915–16	177	4,531	1919–20	1,413	25,278
1916–17	292	6,638			

During the past year 1,240 gamma-ray measurements and 173 other tests have been performed; 23,259 milligrams of radium and 2,019 milligrams of mesothorium were submitted for test. This material has a market value of over $2,600,000.

Seventy-nine preparations containing a total of 1,390 milligrams of radium were certified for export; it was distributed as shown in the table below.

Country.	Number of preparations.	Radium milligrams.	Country.	Number of preparations.	Radium milligrams.
Japan	22	517.3	India	2	29.9
Philippines	11	344.6	Spain	2	29.0
Brazil	9	93.0	Panama	1	25.0
Cuba	6	92.3	Porto Rico	2	22.6
Canada	6	72.5	South Africa	1	16.0
Columbia	2	49.8	Peru	1	9.9
Italy	7	49.6	Holland	3	6.2
Australia	4	32.1			

Luminous Materials.

Self-luminous materials contain a small percentage of a radioactive material, usually radium, and require no previous exposure to light to excite their luminescence. This property is of great value in many fields, both military and civil. These materials are used

for the illumination of airplane dials of all kinds, of bomb sights, compasses, gun sights, round counters for machine-gun magazines, targets for indirect fire, dials for navigation instruments, etc. In civil life they are used for the illumination of dials for clocks and watches, for marking push buttons, pull sockets, signs in dark places, in fact wherever a faint and entirely self-contained illumination is desired.

When the Bureau began the study of these materials in 1916 but little was known and nothing had been published concerning their properties. In particular nothing was known regarding the effective life of the material and but little information was available regarding the brightness that is needed for various purposes. Both are of prime importance in the practical use of these materials. After developing suitable methods for measurement it was to these problems that the Bureau directed its attention.

A considerable amount of data had been obtained by the time the United States declared war with Germany. This was at once placed at the disposal of the Departments of War and Navy and from that time to the present the study of problems of special interest to these departments has largely supplanted the more orderly investigations of the initial problems. Material bearing upon the latter has, however, been accumulated throughout this time and will be collated with the earlier observations as soon as a sufficient staff can be provided to carry the routine testing and have some time free for more constructive work.

During the past year even the tests of luminous materials have been almost entirely crowded out by the large amount of work required in the gamma-ray tests of radium. However, during the first half of the year the Bureau cooperated with the Ordnance Department of the Army in the study of luminous targets and of radium lamps for reading scales. Measurements were also made on the brightness of a number of luminous gun sights both before and after field use.

Cordial relations with the manufacturers and civilian users of these materials have been maintained. Many requests have been received from the latter for information and advice. These requests have been complied with to the extent of our ability, but many pertinent and important questions concerning these materials are still unanswered, and can be answered only by the careful work of an authoritative institution, such as this Bureau, that is able to carry on the work over a term of years.

X Rays.

As indicated above, the Bureau's X-ray investigations have for the present been practically discontinued. During the year a few tests of protective materials have been made, and for other sections of the Bureau some radiographs of samples of metal and of wood have been taken.

By costly experience roentgenologists have learned that the protection of themselves from X rays is of utmost importance. This protection is obtained by the use of lead and of lead-impregnated materials, notably lead glass and lead rubber. When the Bureau began its study of these protective materials it was found that some materials offered for protection were entirely worthless and few of

them were as efficient as desired. The Bureau has been markedly successful in securing an improvement in the quality of these materials, but the continuation of this improvement is dependent upon the provision of additional support for the work.

Roentgenologists are thoroughly awake to the need for the study and testing of all types of X-ray apparatus and materials and desire the Bureau to take a commanding position in this work. The many demands made upon the Bureau have, however, prevented it from giving to the X-ray work the support that it deserves and requires.

PUBLIC-UTILITY STANDARDS.

Public-Utility Investigations.

A large and important field of work, including more of engineering and field work than most of the electrical work so far described, is concerned with the various public utilities, particularly electric light and power, gas, street railway, and telephone companies. The work includes (1) scientific and engineering research, (2) the study of public-relations questions, (3) the preparation of specifications regarding the quality of public-utility service, (4) methods of testing and inspection employed by municipalities and commissions, (5) safety rules for use by the utility companies to safeguard their employees and the public, and (6) the collection and distribution of information by published papers and through correspondence.

This work is a natural outgrowth of the research and testing work done by the Bureau of Standards for the public-utility companies for several years. The testing of electrical instruments and meters, of gas lamps and the standards employed in measuring the candlepower and heating value of gas, the life testing of electric lamps, the testing of instruments used in telephone work, research on electrolysis mitigation, and similar investigations and tests connected with the public utilities, have all involved to a greater or less degree questions of standards of service in the various public utilities. The Bureau has gradually accumulated a considerable amount of information on these questions and has been able to contribute materially to the establishment of standards of quality in several of these services. Furthermore, it has promoted with marked success the practice of settling disputed questions in this field on the basis of sound engineering and economic principles and of cooperation between interests rather than by legal controversy, and in so doing the Bureau has attained an enviable position as an impartial mediator in such questions. Consequently, during the past three years, when abnormal conditions have given rise to many cases in which readjustment of service standards or of rates has been called for, the public-utility staff of the Bureau has been called upon for an unprecedented amount of work.

Relation of the Bureau to Municipalities and Public-Service Commissions.

In many States the public-service commissions have set standards of service, and the Bureau has cooperated with most of those that have done so. In other States the railroad or public-service commissions have taken no action in the matter, although having authority

to do so. Again, in some States there are no public-service commissions to issue regulations or to inspect the quality and safety of the service rendered by the various utilities. In any case the cities and towns must look after their own interests, in whole or in part, and frequently have taken up such matters very successfully. Even where there are well-equipped and active State commissions, which have adopted rules and are ready to hear complaints regarding rates or service, a very large responsibility rests upon the municipalities. Few State commissions will ever be likely to have a force of engineers and inspectors large enough to enable them to take the initiative in every case and relieve the municipalities of all the responsibility. On the contrary, if the municipalities are active and enterprising in their own behalf, and if the larger ones have well-equipped public-utility departments which can prepare the city's complaints or requests and take them up to the State commissions for hearing and adjudication, the State commissions will be better able to serve all the municipalities of the State, and the municipalities will enjoy in large measure the advantages as well as the responsibilities of home rule without its greatest disadvantages.

For most cities and many commissions it is a difficult matter to judge the quality of service rendered by its utilities. The studies made by the Bureau are a great help in this connection, but much remains to be done. It will conduce to fairness and a good understanding to have the subject studied further and to have specifications as definite and complete as possible made available for all branches of public-utility service.

Obviously, it will never be practicable for any State commission or city to handle these questions alone. Though they possess large and able engineering staffs or employ specialists for each separate problem, the question of what is good service or whether the service in any given case is adequate, safe, and satisfactory can be settled only by reference to what is done under similar circumstances elsewhere in the country. In other words, standards of good practice and good service are largely determined by general experience and should be studied comparatively, using the experience of the entire country. The Bureau has been doing this for several years, and although it has not been able to do as much as it would have liked, it has done enough to demonstrate the practicability and acceptability of the method. The success and approval which the work has met so far fully justify its greater development.

GENERAL CONDITION OF THE DIVISION.

During the war the demands for testing and research for the military departments were so numerous that the resources of the electrical division, as of other parts of the Bureau, were largely devoted to such service, and its experienced staff trained in experimental work was an invaluable asset. Since the cessation of hostilities, however, the situation of the division has grown increasingly difficult. The calls for service from the Government and from the industries have increased greatly, while the staff has become less capable of meeting them, not merely because of the decrease in numbers made necessary by the reduction of funds, but even more because of the continual loss of experienced and capable experts who have had to be replaced by

untrained ones. Of the 148 persons attached to the division on July 1, 1920, 90 had been here less than two years and 46 less than one year. Moreover, 24 were either serving temporarily or were known to have plans for leaving in the near future. This situation has already seriously affected the productivity of the division, especially in fundamental electrical investigation. Unless more adequate support can be obtained, and a salary scale established which will enable the Bureau to obtain capable scientific assistants and to retain them for a reasonable time, it can not hope to maintain the high standing in this field which has been won by years of labor. A staff of trained investigators can not be built up in a month or a year, and if the present situation is not remedied soon the damage to the Bureau through loss of its experienced men will be well-nigh irreparable.

3. HEAT AND THERMOMETRY.

Establishment of the standard scales of temperature throughout the range of measurable temperatures; testing and standardization of thermometers, pyrometers, and other temperature-measuring instruments; determination of specific and latent heats, heats of reaction, melting and freezing points, and other properties of materials in the determination of which precise heat and temperature measurements are the principal requirements; standardization of calorimeters; production and distribution of standard heat and temperature samples; industrial applications of heat and temperature measurements; determination of fundamental engineering data involving thermal constants; determination of the fire-resistive properties of structural materials; investigations relating to automotive power plants, fuels, and lubricants.

THERMOMETRY.

This section is concerned with researches on the standard scale of temperature and thermometric fixed points from the lowest attainable temperature up to about 500° C.: maintenance of working standards within the above range: methods of standardizing temperature-measuring instruments, such as liquid in glass thermometers, vapor-pressure thermometers, resistance thermometers, thermocouples; the testing and certification of temperature measuring instruments; and methods of measuring temperatures.

Clinical Thermometers.

Inasmuch as a large proportion of the clinical thermometers sold to the public were believed to be unreliable, a conference representing the several governmental agencies concerned and a number of the manufacturers was held at the Bureau to consider means for improving existing conditions. There was little difficulty in arriving at a decision as to the accuracy and reliability requirements necessary to protect the public and which at the same time would present no unreasonable manufacturing difficulties.

With a view to obtaining more reliable information as to the conditions existing in the trade, the Bureau, at the request of the manufacturers, undertook to secure representative samples of clinical thermometers on sale or in use in hospitals. A considerable number of thermometers were obtained for this test, the results of which will be available during the early months of the next fiscal year.

Standard Temperature Scale.

The standard scale of temperature adopted by the Bureau as its working standard scale in the interval −40° to +450° C. is that defined by the resistance thermometer of pure platinum standardized at the temperature of melting ice (0°), of steam condensing at normal

atmospheric pressure (100°), and at the temperature of the vapor of sulphur boiling at normal atmospheric pressure (444.6°). The working scale previously used in the interval 0 to 100° C. was the international hydrogen scale as distributed by the International Bureau of Weights and Measures through the intermediary of mercury in glass (verre dur) thermometers. To ascertain the order of agreement of these two scales, a series of comparisons was made between a number of verre dur standard thermometers and several platinum resistance thermometers. The agreement between the mean hydrogen scale defined by all the verre dur thermometers included in these intercomparisons and the scale defined by the platinum resistance thermometers was found to be practically within the limits of accuracy with which the former can be used (about 0.005°). The only indication of a systematic difference between the two scales was found in the interval 0 to 30°, where the indications of the resistance thermometers were uniformly higher, attaining an average difference of 0.005° from 10 to 25°.

Industrial Thermometers.

An investigation of industrial thermometers under various conditions of use was undertaken for the purpose of obtaining data which would be useful in specifying the methods for testing and calibrating these instruments. A number of representative types of industrial thermometers were loaned by the manufacturers for this investigation. The results so far obtained may be summarized in the statement that for most of the types in common use, the indications, for a given temperature of the medium the temperature of which is to be measured with the thermometer, are very largely influenced by the character of the medium, its rate of circulation, and the character of the mounting of the thermometer. Thus the indications of a certain thermometer were found to differ by over 100° F. when it was used in rapidly circulating oil and air, respectively, both at the same temperature. Therefore many types of industrial thermometers can not be used to measure true temperatures unless calibrated under conditions of use, although they may still be useful as indicating instruments showing changes in temperature or for reproducing identical temperature conditions from day to day. Obviously, if one thermometer is replaced by another of different type, its indications may be different for the same true temperature. When opportunity affords, the tests will be extended to the measurement of the temperatures in saturated and superheated steam. Although superficially the two cases are very similar, it seems probable that differences will be found quite as great as between measurements in circulating oil and air, respectively. This is due to the fact that saturated steam supplies heat very rapidly to colder objects by condensing upon them, while superheated steam has in this respect the properties of a gas. The results so far obtained will be included in a report which will be submitted to manufacturers and others interested.

Melting Points of Greases.

This section was requested by the oil committee of the Bureau to investigate various methods used in determining the melting points of lubricating greases and to select a standard method for making the determination.

Methods recommended in the literature on this subject and those used by commercial firms were investigated. A method differing in slight details only from that known as "Pohl's" was finally adopted after careful consideration of the others investigated. This method may be briefly described as follows: A thin coating of grease is applied to the bulb of a thermometer, the general construction of which is specified. This thermometer is then suspended in a test tube immersed in a water bath, or for higher temperatures in an oil bath. The temperature at which the first drop of grease flows from the bulb is called the melting point of the grease. The method was applied to a large number of greases and the results indicated that an accuracy of from 1° to 2° C. could be obtained.

Specifications for Standard Chemical Thermometers.

At the request of a committee from the American Chemical Society, specifications were drawn up for three proposed standard types of chemical thermometers. The intention of the committee is to provide a small number of chemical thermometers of standard design which can be used for a very large number of measurements. The specifications for these thermometers when approved by the committee will be submitted to the manufacturers of thermometers. It is thus hoped that a uniform type of thermometer can be secured at a reasonable price, and that the agreements of results obtained in different laboratories will be much more satisfactory if one type of thermometer is used for a given measurement.

Testing Equipment.

The greater part of the testing equipment of the thermometric laboratories was designed primarily for work of high precision. The increase in the amount of testing of thermometers of ordinary grade has made it necessary to supplement this equipment with comparators designed to permit more rapid testing while insuring the required accuracy. With this end in view, an electrically heated water-bath comparator for testing in the interval 10 to 90° C. and an electrically heated oil-bath comparator for testing in the interval 100 to 325° C. were designed and the construction nearly completed. The comparators will accommodate as many as 24 thermometers.

A portable electrically heated steam point apparatus was also designed and constructed for use in the thermometric laboratories.

HIGH TEMPERATURES.

This work includes researches on the standard scale of temperature and thermometric fixed points in the interval from 500° C. up to the highest attainable temperatures; maintenance of working standards in the above range; standardization and distribution of standard samples for thermometric fixed points [for example, a series of pure metals of certified melting points]; methods of standardization and the testing and certification of pyrometers, such as thermocouples, resistance pyrometers, pyrometer galvanometers, optical pyrometers, including absorption glasses and color screens, radiation pyrometers, etc.; physical properties of materials at high temperatures, such as emissivity, monochromatic, and total, specific heats, melting points of refractories, metals, fire brick, etc.; ionization and

radiation in gases and vapors, etc.; industrial pyrometry and the measurement of the temperatures in industrial processes; and the annealing of glass.

Industrial Pyrometry.

At the symposium on pyrometry held at Chicago in September under the auspices of the pyrometer committee of the National Research Council nine papers were presented by members of this section. Some of the work in industrial pyrometry was reported upon at this time. The papers which have been published this year embrace treatises on thermoelectric pyrometry, optical and radiation pyrometry, recording pyrometry, high-temperature control, standard scale of temperature, melting points of refractory materials, and pyrometry in rotary Portland cement kilns.

A book of about 350 pages, 160 illustrations, tables, etc., on the methods of pyrometric practice has been prepared and will appear as a technologic paper of this Bureau. All the methods of pyrometry in present-day use are described. Methods found desirable for the calibration of all types of pyrometers are presented in detail. The use and care of instruments are considered, and attention is given to the modern extensive installations of pyrometric equipment, wiring diagrams, etc., suitable for large plants. One section of the book is devoted to pyrometric methods and installations for specific industrial processes.

Standard Samples for Thermometric Fixed Points.

The Bureau issues samples of various materials, the melting or freezing points of which have been determined with high precision. By this means the standard temperature scale of the Bureau may be distributed to the various technical laboratories. The supply of several metals was exhausted last year but has now been replenished by 1 ton of lead, 1 ton of copper, and several hundred pounds of zinc and tin. The melting points of these metals have been determined during the present year and the material has been divided into about 3,000 standard samples.

Heat Treatment of Glass.

The investigation of suitable methods for the annealing of glass has been continued. Glass for use in optical instruments as lenses, etc., must be so annealed as to remove all stresses producing warping of the surfaces and optical inhomogeneity. The strain tending to cause changes in the volume of thermometer glass must be removed and the annealing of ordinary glassware should be so carried out as to reduce to a minimum all strains tending to cause breakage. The annealing temperature and process of cooling various glasses have been investigated in detail. Two papers have been published and others are in preparation.

A number of manufacturers have submitted different kinds of glass for test in order to obtain directions for annealing. Several extensive reports of a confidential character have been prepared for various Government bureaus and manufacturers.

Considerable work has been completed on the "tempering" of glass. In certain processes of heat treatment whereby strain of a

definite character is introduced a fairly nonbreakable glass may be produced. Such glass has been employed for goggles, etc.

Investigations in Electronics.

When electrons having velocities in general less than 300,000,000 centimeters per second (about 1,900 miles per second—a small velocity for electrons) collide with molecules of gas or vapor the collision is usually nearly elastic. That is, the electron after the impact has the same velocity as before the impact. There are certain critical velocities in this range, however, for which the collision is inelastic and the molecule absorbs a definite amount of the kinetic energy of the electron. One general type of inelastic collision results in a rearrangement of the electrons forming the molecule. Another type causes the ejection of an electron from the molecule, leaving the molecule positively charged. Still other types of collision result in a dissociation of the molecule into charged atoms. One result of such collisions is the production of light. Hence a study of the types of collision occurring in various gases and vapors is of importance from the standpoint of illumination and may lead to a more efficient form of electric light. Research of the above character has already found many commercial applications in technical fields, for example rectifiers and arc lamps. Such investigations are now being carried on in many laboratories in this country and abroad in order to advance our knowledge of the ultimate structure of matter.

The work on metallic vapors reported last year has been continued and extended to nonmetallic vapors and gases, including the vapors of several compounds. Four papers have been published during the year and two others are now in press. These include measurements of the ionization and resonance potentials of lead, calcium, nitrogen, oxygen, hydrogen, phosphorus, sulphur, and iodine, a critical investigation of the theory and operation of arcs in caesium vapor, determination of several fundamental physical constants, and a description of a new method of measuring photographic density of spectral lines.

HEAT MEASUREMENTS.

Measurements are made in this section over a wide range of temperatures of thermal properties of materials, such as specific heats, latent heats, pressure-volume-temperature relations for liquids and gases; heats of reaction, particularly heats of combustion of solid, liquid, and gaseous fuels; heat transmission and thermal conductivity. Work is also done on the development of calorimetric apparatus and methods; and on methods for temperature control, pressure measurements, measurement of heat transmission, etc.

Practically all of the research work of this section during the year has been devoted to the determination of those fundamental physical constants of materials which find application in refrigeration engineering.

Vapor Pressure of Ammonia.

The results of the numerous measurements of the vapor pressure of ammonia referred to in the previous report have been completed

and prepared for publication and have been published. (See list of publications.)

Vapor Pressure of Carbon Dioxide.

Numerous measurements have been made during the year of the vapor pressure of liquid carbon dioxide in the range between the triple point and the critical temperature, using methods and equipment similar to those used in the work on ammonia. The completion of this research has been delayed by unexpected phenomena requiring further careful investigation.

Specific Volume of Liquid Ammonia.

Measurements have been made at various times during the past few years of the density of samples of liquid ammonia of high purity, prepared by several methods, using calibrated glass picnometers. Determinations were made throughout the temperature interval −78 to +100° C., and the accuracy obtained was of the order of a few parts in 10,000. During the present year the experimental work was completed, the computation finished, and the results were prepared for publication.

Specific Heat of Sodium Chloride Solutions.

This work, which was completed several years ago, was not published due to the fact that the author left the service of the Bureau before the material had been prepared for publication. The results of this investigation have now been worked up and made ready for printing. The work includes determinations of the specific heats of a number of solutions of various densities, at temperatures between their freezing points and +20° C. The data furnished by this investigation, taken in connection with those described in the following paragraph will be used in the preparation of tables of the properties of brine, for the use of refrigerating engineers.

Density and Thermal Expansion of Sodium Chloride Solutions.

The experimental work relating to the density and thermal expansion of sodium chloride solutions in the temperature interval between their freezing points and +50° C. has been completed and the results prepared for publication in cooperation with the divisons of chemistry and of weights and measures.

Specific Heat of Gases.

Development of a flow calorimeter to measure specific heat of gases has been actively pursued.

The chief progress has been in the direction of perfecting technique of construction such as to permit refinement of the design at points where the preliminary experiments have shown the need for improvement. The aim is to produce an instrument which will permit accurate measurements of the heat capacity of a gas at temperatures from −80 to +150° C. at any pressure up to 1,500 pounds per square inch. Because this heat capacity is small for a given volume of gas, it is essential that the construction be at the same time delicate and robust—delicate in the sense of small mass of material used so that the physical magnitude observed be not overburdened by bulk of

apparatus, and robust in the ability to withstand the stress due to the pressure.

The construction has progressed to the point of the final assembling of the instrument. The next step is to put it in operation and to construct and set up numerous accessories, such as thermo-regulated baths, evaporators, condensors, pressure regulator, flow gauges, pressure gauges, and various electrical measuring equipment.

Testing of Thermal Insulators.

Testing of thermal insulators has been carried on at the Bureau for a number of years, and results of tests of a large number of materials used for insulation have been published. There has been a demand from refrigerating engineers for the standardization of tests of insulating materials along the lines which have been developed by the Bureau in order to eliminate the confusion resulting from the use of widely different methods of testing. Specifications for a standardized equipment have been prepared and submitted to the American Society of Refrigerating Engineers.

Preparation of Pure Materials.

In cooperation with the chemistry division supplies of pure ammonia, ethyl chloride, and carbon dioxide were prepared. The ammonia and carbon dioxide after drying were further purified by fractional distillations. The ethyl chloride was prepared and further purified by fractional distillations. These materials were intended for work on the determination of those physical properties which are of importance in refrigeration engineering.

THERMODYNAMICS.

With the reorganization of the division of engineering physics some of the functions (including work in pure and applied thermodynamics) previously cared for by this section were transferred to that division. The physicist formerly in charge of this section was transferred at the time of reorganization. When circumstances permit, the work will be resumed.

CRYOGENIC LABORATORY (LOW TEMPERATURES).

This work is concerned with the production of low temperatures down to those of liquid hydrogen (ultimately liquid helium), preparation and storage of pure gases, development of methods of producing and maintaining low temperatures, liquefaction and separation of gases at low temperature, and special tests requiring the facilities of the low-temperature plant.

Operation of Plant.

The liquid-air plant has been operated about once a week. Since the liquid air can be stored for several days this has made it possible to keep a supply in stock the greater part of the time. It has been used for investigations in the low-temperature laboratory and supplied to various other laboratories at the Bureau, and also furnished to a number of other institutions in Washington and the vicinity.

The carbon-dioxide, low-temperature system was operated almost daily to provide cooling for thermometer comparators, the investigation of refrigeration constants, the testing of aviation instruments, and other purposes.

Generators for acetylene, hydrogen, and oxygen were maintained in operation, and these gases were supplied to other laboratories.

Hydrogen Liquefier.

A hydrogen liquefier designed several years ago was completed and installed during the year. It is believed that this equipment will be capable of producing sufficient quantities of liquid hydrogen for present needs, and its operation will provide a basis for the design of permanent equipment for the production of liquid hydrogen in considerable quantity.

Liquid Oxygen for Use by Aviators.

Work is under way on a container for liquid oxygen to be used in high altitude airplane flights to supply oxygen for respiration.

FIRE-RESISTIVE PROPERTIES OF STRUCTURAL MATERIALS.

In this section the standardization of fire tests is investigated; fire tests of structural materials and structures are carried on, as well as investigations to develop engineering data relative to the fire-resistive features of building construction; tests of fire-retarding devices; and investigations of building codes and fire codes.

The object of the investigations on the fire-resistive properties of structural materials is to furnish architects, construction engineers, builders, State and city building bureaus, insurance interests, and others with fundamental engineering data relating to the behavior and safety of various types of building material and construction when exposed to different conditions met with in fires.

Fire Tests of Building Columns.

The results of the series of fire tests of building columns jointly conducted by the Associated Factory Mutual Fire Insurance Cos., the National Board of Fire Underwriters, and the Bureau of Standards have been prepared for publication and will be issued as a joint report by the cooperating organizations, and also as a number in the Bureau's technologic series, both of which will probably be available in printed form at an early date. The investigation comprises fire tests of 106 building columns representative of current building practice in material, design, and methods of protection. General notes on the purpose, scope, and methods of testing employed have been given in previous reports, with summary of some important test results. The reduction of the large mass of experimental data into forms suitable for publication was accomplished during the progress of the tests and in the period immediately following their completion. General comparative diagrams and tabulations were subsequently prepared and bases of interpretation established to give the test results the nearest possible approach to direct practical application. The forthcoming publication will be of about 400 pages, nearly one-half of which consists of illustrations, dia-

grams, and general tabulations, an effort having been made to secure as much brevity as was consistent with adequate presentation.

Strength of Materials at High Temperatures.

Brief description of an apparatus for determining the compressive strength and elastic properties of materials as affected by heat, and notes on results obtained in a preliminary series on structural steel, have been given in previous reports. During the year further tests of steel have been made and some preliminary work done on concrete and timber. The tests of concrete indicate that at temperatures resulting from fire exposure of structural members the expansion of concrete under load is much lower than at normal temperature, a fact that has a decided influence on the physical behavior of composite members of concrete and steel or cast iron when exposed to fire.

The tests of timber, which have as yet been made on only one species, show large reductions in strength at temperatures near 100° C., although not such as to cause failure under working loads. Beyond 150° C. further decrease in strength was marked, failure under working loads being imminent before 200° C. was reached. On cooling the timber regained a large proportion of its original strength.

Pyrometer Lag.

The importance of determining the characteristics of indication of pyrometers when used for measuring rapidly rising and falling temperatures, as is incident with fire tests of structural members, led to an investigation which has been completed as far as it concerns the pyrometer type, used in the jointly conducted fire tests of building columns. Statement of essential results attained is given in the report of the column investigation noted above. The effects due to the heat insulating and absorbing properties of the mounting and couple wires were found to be very large near the beginning of the test, and caused the pyrometer indications to be too low by several hundred degrees centigrade. The differences became rapidly smaller and after one-half hour immersion in the furnace chamber the error due to this cause was quite small.

Another source of error investigated was that due to radiant heat interchange between the pyrometer and the inclosing walls, which latter, in a furnace where the source of heat is combustion within the chamber, are at lower temperature than the furnace gases. For the type of furnace and size of pyrometer used the error was found to be about 150° C. near the beginning of the test, with gradual decrease to less than 50° C. at the end of an eight-hour run.

The investigation discloses the difficulties involved in temperature measurements under the given conditions and the need of standard methods if comparable results are to be obtained with different furnaces and pyrometer equipments.

Fire Tests of Concrete Columns.

The experimental work relating to the fire-resistive properties of concrete columns, which has been under way for several years at the Pittsburgh laboratories of the Bureau, was completed during the year.

A brief summary of the nature of these tests and some of the more general conclusions have been given in previous reports.

The investigation included a comparison of the fire resistance of four types of columns made from the same aggregate, a comparison of the fire resistance of similar columns made from seven types of aggregates, and a comparison of the effectiveness of several methods of providing special protection for columns which without such protection did not give favorable results in the fire test.

In the entire investigation 90 column tests have been made, of which 62 were fire tests, 16 were compression tests of columns which had not been fire tested, and 12 were compression tests of columns which had been fire tested, but which after four hours of fire test did not fail, while hot, under the maximum load obtainable with the furnace-loading equipment. Of these 90 tests 28 have been made since June 30, 1919.

The results obtained indicate that concretes may be divided, with respect to their fire-resistive properties, into two general classes, those which show a tendency to spall when exposed to fire and those which do not. The tendency to spall was observed in concrete made from aggregates consisting largely of quartz or granite, and such concretes made the poorer showing in the fire tests. Full details of results relating to the behavior of the different types of columns, aggregates, and protective devices which have been tested were given in progress reports made to the American Concrete Institute and published in its proceedings for 1918, 1919, and 1920. A complete report of the investigation is to be published as a technologic paper by the Bureau.

Fire-Resistive Properties of Wall Plasters.

In most dwelling houses and in a very large proportion of the buildings of other types the interior surfaces are covered with plaster of one kind or another. Many exterior walls are covered with plaster, under the name of stucco. The materials used in plastering being, for the most part incombustible, wall plasters, both interior and exterior, afford some protection against fire and because of the extent of their use it is of importance to have definite information as to the amount or degree of fire protection afforded, in different kinds of structures by various plasters. A considerable amount of information of this character has been gained by a series of fire tests of specimens made from plasters of many compositions.

Plaster specimens were made 26 inches square and either 1 or 2 inches thick, with metal lath embedded next to one surface. A small gas furnace was built, capable of accommodating four test specimens. The furnace was heated in accordance with the standard time-temperature curve for fire tests, and measurements were made of the heat transmitted through and of the deformation of the plasters.

The materials tested included a large number of mixtures, not only those in common use but other combinations of materials which appeared to be worthy of consideration, particularly in view of the possibility of usefulness for the protection of steel and of load-bearing concrete in fire-resistive construction. This usefulness depends on a number of properties, including heat insulating efficiency

and ability to remain in place when exposed to heat. Both of the above tests were designed to give information bearing on these properties.

In addition to the materials ordinarily used in commercial plastering, mixtures containing asbestos and others containing kieselguhr were included.

It was found that differences in rate of heat transmission through different plastering mixtures containing large proportions of sand are not great enough to be of importance in the fire resistance of the plasters. Gypsum wood fibered plaster, plaster containing asbestos and mixtures containing kieselguhr showed superior insulating properties.

All highly sanded mixtures such as are in common use in building operations showed rapid expansion when exposed to fire. Specimens made from mixtures of gypsum plaster and sand or of gypsum, lime, and sand, in which the sand content was low, showed initial expansion followed by shrinkage. No combination of these materials was found which would bear exposure to heat, under the fire-test conditions, without deformation. One of the most promising mixtures, in point of deformation, and one which also showed fair heat-insulating properties was a mixture of Portland cement and crushed cinders, the latter being used to take the place of sand. Specimens made from this mixture showed a small initial expansion followed by a slight shrinkage. The performance of this mixture indicates that it would be greatly superior to mixtures of Portland cement and sand as far as staying in place under fire conditions is concerned. It is probable that it would also resist a hose stream after exposure to fire.

This investigation is to be continued to include tests on large specimens in the Bureau's panel-testing furnace, which has been described in previous reports.

Temperatures Attained by Protected Steel in Floor and Roof Slabs Under Fire Conditions.

The small furnace used in fire tests of plasters was also used in tests made to determine the temperatures attained by the steel in gypsum roof slabs in which the steel was protected by three-fourths inch of the material, and also in similar slabs with an additional protection of three-fourths inch of wood-fibered plaster. Similar tests were made with sections of concrete floor slabs with the steel reinforcing rods located at depths of $\frac{1}{2}$, 1, and $1\frac{1}{2}$ inches from the surface representing the bottom of the floor slab which was to be exposed to the heat in the fire test. The aggregates used included blast-furnace slag, gravel, bituminous cinder, and limestone. The standard time-temperature curve for the fire test was followed, the tests being of four hours' duration. Temperatures were measured by means of thermocouples attached to the steel.

As was shown by tests reported last year, structural steel may be expected to fail, under its working load, at temperatures below 575° C. Steel in the gypsum roof slabs protected by three-fourths inch of material attained this temperature in approximately 1 hour 50 minutes. In roof slabs which had the additional protection of three-fourths inch of wood-fibered plaster, making $1\frac{1}{2}$ inches in all

protecting the steel, the temperature of 575° C. had not been reached at the end of the four-hour fire test.

In the fire tests of concrete floor slab sections, the rate of heat transmission to the steel did not vary greatly with the different kinds of aggregates, though there was a persistent difference in favor of the limestone aggregate in this respect.

In general, it may be said that steel at a depth of one-half inch reached the 575° C. point in less than one and one-half hours; at a depth of 1 inch this temperature was reached in less than two and one-half hours, except in limestone concrete specimens; at a depth of 1½ inches the same temperature was reached within three and one-half hours in most cases.

These results show that the thickness of concrete protection ordinarily provided for steel in floor slabs, beams, and girders is inadequate for its proper protection during severe fires of long duration, even assuming that the protective concrete were to remain in place throughout the fire. A technologic paper will be published covering this series of tests.

AUTOMOTIVE POWER PLANTS, FUELS, AND LUBRICANTS.

Investigation of the fundamental, scientific, and technical problems related to the design and operation of internal-combustion engines and accessories, and the qualities and characteristics of fuels, lubricants, etc., for use in such engines are conducted by this section.

An increasing demand on the part of the automotive industry for research in fundamental problems of this industry has developed, as anticipated, during the year, but a looked-for decrease in the demands on the section for researches in the field of aeronautics has not developed. In fact, the demands along some of these lines have increased. As a result, the section has been called upon to cover a rather wide field of activities, including all classes of automotive power plants.

Altitude Laboratory.

When an aircraft engine is flown at high altitudes the power of the engine is very much less than at ground level. Other features, such as air temperatures, oil temperatures, load, etc., differ radically from ground-level conditions.

The Altitude Laboratory, built especially for the study of these problems, has been used for studying the performance of the Liberty "12" engine and the Hispano-Suiza 300-horsepower engine for the Air Service, Engineering Division, Dayton. Reports describing this work have been prepared for publication. A comprehensive research covering all features of performance of the Hispano-Suiza 180-horsepower engine, with special reference to means for increasing the power and fuel economy at high altitudes, was also undertaken.

Two general methods are available for improving the power and fuel economy of aircraft engines at high altitudes; these are by supercharging and by supercompression. The former involves the addition of some type of blower or compressor to increase the pressure of the air taken into the cylinder, while the latter makes necessary an increase in the compression ratio, i. e., the extent to

which the combustible charge is compressed before firing. Its application requires an accurate knowledge of the effect of changes in compression on power and economy. This information is made available by the investigation referred to above.

Minor problems completed include, (*a*) tests of exhaust valves of special alloys; (*b*) a comprehensive general analysis of the various factors in engine performance at high altitudes.

Lubrication of Automotive Engines.

The development of a lubrication laboratory with special reference to study of lubrication problems in automotive engines was begun in 1918, hence much of the time has been devoted so far to the development of apparatus and methods.

A series of tests were run in a typical aeronautic engine to determine, if possible, any difference in lubricating value of oils from different classes of crudes. The results showed no significant differences between properly refined oils from different sources, provided the oils are chosen with equal care to meet the conditions of operation.

A series of routine laboratory tests was run on samples of all trade-marked oils sold on the market and which could be secured by the Bureau. The results will serve as a guide to purchasers of oil and it is hoped will be of much value when published in the near future.

A new method of distillation has been perfected for the analysis of lubrication oils, which has proved to be of great value. By the use of superheated steam at very low pressures, in a special still, it is possible to fractionate ordinary lubricating oils and determine their composition with, in most cases, a negligible amount of decomposition. This process gives promise of important applications in the refining of oils.

Other problems which have been undertaken are (*a*) the relative effects on different classes of oils of dilution by fuels escaping into the crank cases of engines, (*b*) the extent to which fuel vapors are dissolved in different classes of oils.

No significant differences betwen oils in these respects were found.

The tendency of oils to form so-called carbon deposits in engine cylinders has been investigated to some extent during the year. Further investigation of the oxidation test and the demulsibility test developed by the Bureau has been made in this connection.

Tests of 25 commercial brands of automobile oils were carried out in cooperation with one of the large automobile manufacturers. A number of special types of automobile oils were also tested for the inventions section of the War Department.

Cooling Problems.

The general features of a very comprehensive investigation of the problems involved in the cooling of circulating water for aircraft engines by means of so-called radiators were completed last year. This work has been followed during the current year by (*a*) tests of a considerable number of new radiator designs for the Air Service of the Army; (*b*) detailed investigations of the conditions of pressure, temperature, and velocity occuring within the air spaces of typical radiators and of experimental air tubes; (*c*) mathematical

and limited experimental application of the results previously obtained to the cooling of "air-cooled" engine cylinders.

A study has been made of the radiator requirements of an engine when operating at altitudes with a supercharger as mentioned under "Altitude laboratory."

A series of experiments were run for the Navy Department to determine the practicability of a method for recovering water from the exhaust gases of engines used in airships. A number of experiments were carried out to determine the pressure drop and heat transfer in a special exhaust pipe section made up for this investigation.

The recovery of water is required for helium airships as otherwise the reduction in total weight by consumption of fuel would require the loss of gas. Helium is too expensive and the available supply too small to permit its general use without some such device for its conservation.

The results of the investigation of cooling problems have been of special service to the Engineering Division, Air Service, in the design of cooling systems for new types of airplanes. The latest cooling devices promise important improvements in efficiency.

Five reports covering work during the current year on cooling problems have been completed and will be published in the Fifth Annual Report of the National Advisory Committee for Aeronautics, as noted under the heading "Publications."

Two papers dealing with cooling problems were published in technical journals.

Carburetion.

The laboratory for research on carbureter problems has been used for tests of a number of carbureters, including the following: White Co., Browne, Mitler, German Zenith (from German motor truck) U. & J.

A mathematical analysis of the laws of flow involved in one method of compensating for the effects of change in air density at altitude has been completed. Similar analyses of other methods are required.

The fuel economy and power of an internal combustion engine depend upon the condition of the mixture as regards temperature, vaporization of fuel, degree of mixing, etc. An investigation of this problem has been in progress.

Essential to this investigation is a knowledge of the vapor pressures and vapor volumes of the customary fuels. Apparatus for measuring these quantities has been in use for some time and results have been obtained on a number of fuels.

The carburetion research has been undertaken mainly at the instance of the Air Service and of the National Advisory Committee for Aeronautics, but some features of it are of equal interest to the manufacturers and users of all types of automotive appliances.

Ignition.

Ignition problems have been handled jointly by this and the electrical division of the Bureau and a portion of the work is described on page 56 of this report. A number of magnetos and one battery ignition system have been tested as to their characteristics and performance.

The effects of various factors on the voltage required to produce a spark at the terminals of various types of spark plugs under operating conditions have been determined. The results of this work are of special importance in providing for reliable ignition on engines operating at high altitudes with a supercharger.

A special research was undertaken to determine definitely the cause of occasional failures of ignition in aircraft engines apparently due to faulty spark plugs. The results were to demonstrate conclusively that early ignition of the cylinder charge due to overheated spark plug terminal was the cause. Types of construction which tend to aggravate or to prevent this effect were determined. The cylinder pressures resulting from such preignition were also shown to be some three times normal pressures and to constitute an enormous accidental overload on the engine parts.

Phenomena of Combustion.

A knowledge of the phenomena which accompany the burning of fuel in engine cylinders is of importance in the design and improvement of such engines. A study of some features of the problem has been in progress for several years.

A method previously devised of measuring the rate of progress of the explosion flame in an engine cylinder has been applied to a determination of the effects of spark timing, fuel-air ratio, and turbulence on the flame speed. Direct visual observation of the flame in a cylinder has been made possible by a special type of sight plug or widow which will withstand explosion pressures.

Rates of combustion in mixtures of air and gas at ordinary pressures have been measured by direct observation and photographic records of the shape of free gas flames under definite conditions. The results obtained by this method supplement those by direct observation.

A paper entitled "A Study of the Velocity of Flame Propagation in the Cylinders of Aircraft Engines" was prepared for publication in the technical press.

Fuels.

The situation of the country as regards motor fuels is such as to demand greater efficiency and economy in their use. To meet this situation a comprehensive program of research has been laid out in cooperation with the Bureau of Mines and the Society of Automotive Engineers to make available to designers, manufacturers, and users of automotive apparatus such information as will lead to better utilization of motor fuels.

As a part of this program a special research was undertaken to determine the effect of intake manifold temperature and mode of heating on fuel economy and acceleration of typical automobile engines burning commercial gasoline. Results of this research have been communicated to the Society of Automotive Engineers.

A considerable number of special motor fuels have been tested in engine operation for other departments of the Government and for general information.

Dynamometer Laboratory.

A laboratory building for the use of the automotive power plants section was finished last year, and the equipping of this building has now been substantially completed.

The general equipment consists of two vacuum chambers for the testing of aircraft engines under altitude conditions, with their accompanying dynamometers, pumps, refrigerating machines, etc.; one extra 300-horsepower dynamometer for use with aircraft and other large engines; three smaller dynamometers, one 150, one 125, and one 75 horsepower, with their accessories for general engine research; a drum dynamometer (not yet completed) for performance tests of automobiles and trucks; as well as an adequate supply of minor equipment, instruments, tools, etc., for the class of work to be undertaken.

Special equipment for work in cooperation with the Motor Transport Corps and the Society of Automotive Engineers has been completed. This consists of the following units:

1. Equipment for tests of the different designs of power transmitting systems in rear axles for trucks.
2. Equipment for tests of brake-lining materials with a view to standardizing such tests.
3. Equipment for tests of radiator fan belts.

Miscellaneous.

Several special measuring instruments have been designed and constructed for the use of the laboratory. These include (*a*) a cylinder pressure indicator which has been under development for some time and has proved to be an unexpectedly accurate and convenient instrument, and is now in demand by the automotive industry; (*b*) a relief valve type of maximum pressure indicator which has proved successful; (*c*) an instrument for conveniently measuring the clearance space in engine cylinders. This instrument has proved of interest to other industries, such as the building of refrigeration machinery, air compressors, etc., and is likely to prove of considerable value.

A large number of miscellaneous tests have been made during the year for various departments of the Government, including the Inventions Board of the General Staff of the Army, the Motor Transport Corps, Signal Corps, Navy Department, etc.

Several different types of small gasoline engine, such as are used for electric generator sets, were tested for performance and reliability for the Signal Corps.

The following tests of a general nature were carried out during the current year: Compression test of Motor No. 102 for the Willys Corporation, test of a Turner-Long automatic observer for the Air Service, test of a Hoag manifold superheater, and test of a Dempsey valve cycle.

A number of investigations were carried out in cooperation with other Government departments, including tests of a Yarian generator set for the Signal Corps, test of a National Geselschaft engine for the Motor Transport Corps, and investigation of the characteristics of a number of German motor trucks delivered to this country under the terms of the armistice.

INFORMATION, TESTING, AND PUBLICATIONS.

Information, Activities in Societies, etc.

An important part of the division's activities has consisted in furnishing information on scientific and technical subjects related to its work, by extensive correspondence, reports, or directly to technical men visiting its several laboratories. Special reports have been prepared for the military departments on important problems connected with airships. Assistance has been given commercial concerns in suggesting designs for a reinforced concrete cap for timber columns to prolong the fire-protection period for such columns; to a testing laboratory in the design of equipment for fire tests; and to various organizations in the choice of materials for fire-resistive construction.

Members of the division have cooperated in the activities of various scientific and technical societies, including the Society of Automotive Engineers, the American Concrete Institute, American Society for Testing Materials, National Fire Protection Association, the American Physical Society, the Optical Society of America, the American Society of Refrigerating Engineers. Over 30 papers relating to the work of the division have been presented before scientific and technical societies.

Thermometer, Pyrometer, and Heat Tests.

The tests completed in the division during the year are summarized as follows:

The number of mercurial thermometers of all kinds, exclusive of clinical thermometers, submitted for test was 3,267, of which 1,818 were certified and 1,166 received reports, the failure to receive certificates being due either to defects or to the fact that the errors exceeded the established tolerances. Of the remaining thermometers, 141 were broken either when received or in test, and 142 were rejected. Among those submitted were 407 Parr calorimetric thermometers, 120 high-precision calorimetric thermometers, 195 Beekman thermometers, 101 clinical standards, and the remainder laboratory and special thermometers of various types, ranging from below 0 up to 500° C. Of the 25,658 clinical thermometers submitted, 21,946, or 85.5 per cent, were certified. The greatly increased number of rejected thermometers as compared with previous years was due principally to an excessive proportion of defective thermometers in several large lots submitted by the Bureau of Animal Industry. In addition to the above, there were tested 20 resistance thermometers and 20 thermocouples, while freezing-point determinations were made on 20 samples of materials.

Among the miscellaneous tests may be mentioned service tests of locomotive superheater thermometers; comparative tests of various psychrometers; performance tests of deep-sea thermometers of American manufacture, one of which proved fully as satisfactory as any of foreign make, which had before been used exclusively; investigative tests of one type of recording thermometer; and determination of boiling points of eight alcohols in cooperation with Prof. Brunel, of Bryn Mawr College.

The amount of work completed in this section during the year is about 20 per cent in excess of that done in the preceding year and nearly 100 per cent in excess of that done in the fiscal year 1918. This increased work was accomplished with practically the same personnel through modifications in testing methods.

In the high-temperature laboratories, tests of the following instruments were made: Ninety-nine thermocouples, 8 indicating instruments for thermocouples, 9 homogeneity tests of thermocouples, 10 optical pyrometers, and 10 optical pyrometer lamps, 55 melting points, including metals, alloys, and refractories, were determined and 6 special tests were completed. One hundred and thirty-five samples of metals with certified melting points were distributed.

The heat measurements laboratory distributed 443 standard-combustion samples. Several miscellaneous heat tests were made.

Of the routine testing summarized above, about half was done for the Government and half for the public.

In the section dealing with the fire-resistive properties of structural materials numerous investigative tests were made in connection with the researches in progress in that section.

Tests were also made for the Navy Department of the probability of spontaneous combustion in certain sound-proofing materials.

A considerable amount of testing done by the section on automotive-power plants, fuels, and lubricants, being of an investigative character, is summarized under the work of that section.

Publications.

The following papers relating to the work of the division have been published during the year:

Optical and Radiation Pyrometry (Paul D. Foote and C. O. Fairchild): Bull. Am. Inst. Min. and Metal. Eng's. No. 152, p. 1389. August, 1919.

Metals for Pyrometer Standardization (C. W. Waidner and G. K. Burgess), ibid., p. 1511.

Melting Points of Refractory Materials (Leo I. Dana), ibid., No. 153, p. 1571, September, 1919.

Recording Pyrometry (C. O. Fairchild and Paul D. Foote), ibid., p. 1627.

Pyrometry in Rotary Portland Cement Kilns (Leo I. Dana and C. O. Fairchild). ibid., p. 1661.

High Temperature Thermometers (R. M. Wilhelm), ibid., p. 1687.

High Temperature Control (C. O. Fairchild and Paul D. Foote), ibid., p. 1701.

Annealing of Glass (A. Q. Tool and J. Valasek), ibid., p. 1945.

Standard Scale of Temperature (C. W. Waidner, E. F. Mueller, and Paul D. Foote). ibid., p. 2051.

Thermoelectric Pyrometry (Paul D. Foote. T. R. Harrison, and C. O. Fairchild), ibid., p. 2631.

[The above papers are also included in the volume "Pyrometry" published by the American Institute of Mining and Metallurgical Engineers.]

A New Galvanometric Method for Measuring Thermoelectric Emf's. (T. R. Harrison and Paul D. Foote): Jour. Am. Inst. Elec. Eng's, 39, p. 165, 1920.

Melting Point Methods at High Temperatures (L. D. Dana and Paul D. Foote): Chem. and Met. Eng., 22, p. 23, 1920, ibid., p. 63.

Ionization and Resonance Potentials for Electrons In Vapors of Lead and Calcium (F. L. Mohler, Paul D. Foote, and H. F. Stimson): Sci. Papers, Bur. Stds., 15, p. 724, 1920 (No. 368).

Concerning the Annealing and Characteristics of Glass (A. Q. Tool and J. Valasek): Sci. Papers Bur. Stds. 15, p. 537, 1920 (No. 358).

A New Micophotometer for Photographic Densities (W. F. Meggers and Paul D. Foote): Jour. Opt. Soc. Am. 4, p. 24, 1920.

Determination of Plancks Constant h by electronic atomic impact (Paul D. Foote and F. L. Mohler) : Jour. Opt. Soc. Am. 3, p. 96, 1919.

The Ionization and Resonance Potentials of Nitrogen, Oxygen, and Hydrogen (F. L. Mohler and Paul D. Foote) : Jour. Opt. Soc. Am. 4, p. 49, 1920.

The Vapor Pressure of Ammonia (C. S. Cragoe, C. H. Meyers, and C. S. Taylor) : Jour. Am. Chem. Soc. 42, p. 206, 1920. Sci. Papers Bur. Stds. 16, p. 1, 1920 (No. 369).

A Comparison of the Heat Insulating Properties of Some of the Materials used in Fire Resistive Construction (Walter A. Hull) : Tech. Papers Bur. Sds. No. 130.

Fire Tests of Concrete Columns (W. A. Hull) : Proc. Am. Concrete Inst. 16, p. 1, 1920.

Dilution of Lubricants in Crank Cases of Internal Combustion Engines (G. A. Kramer) : Jour. Soc. Autom. Engs., February, 1920, p. 123.

Preignition and Spark Plugs (S. W. Sparrow: Ibid, February, 1920, p. 62.

Flying an Airplane Engine on the Ground (S. W. Sparrow) : Ibid, April, 1920, p. 239.

A Study of the Velocity of Flame Propagation in the Cylinders of Aircraft Engines (R. K. Honaman and D. Mackenzie: Ibid, February, 1920, p. 119.

Design Factors for Airplane Radiators (S. R. Parsons) : Ibid, June, 1920, p. 437.

Some Factors of Engine Performance (V. R. Gage) : Ibid, June, 1920, p. 402.

The Design of Cooling Surfaces for Air Cooled Engines (W. B. Brown) : Autom. Ind., June 10, 1920, p. 1352.

Monel Metal for Engine Valves (S. W. Sparrow) : Ibid, April 15, 1920, p. 904.

The following papers are in press:

Pyrometry and Applications to Glass Manufacture (Paul D. Foote and L. I. Dana) : To appear in Glass Manufacture.

Atomic Theory and Low Voltage Arcs in Caesium Vapor (Paul D. Foote and W. F. Meggers) : To appear as Bur. Stds. Sci. Paper and in London Phil. Mag.

Pyrometric Practice (Paul D. Foote, C. O. Fairchild, and T. R. Harrison) : To appear as Bur. Stds. Tech. Paper.

Ionization and Resonance Potentials of Gases and Vapors (F. L. Mohler and Paul D. Foote) : To appear as Bur. Stds. Sci. Paper.

Pyrometry (G. K. Burgess and Paul D. Foote) : To appear in Standard Handbook for Electrical Engineers, revised.

Specific Heats of Sodium Chloride Solutions, to appear in Jour. Am. Soc. Ref. Engs. and a Bur. Stds. Sci. Paper.

Gravitation and Relativity (C. W. Kanolt) : Lectures given before the Physics Club of the Bureau of Standards, to appear in Jour. Franklin Inst.

Fire Tests of Building Columns (W. C. Robinson, R. E. Wilson, S. H. Ingberg, and H. K. Griffin) : To be published as a joint report of the Associated Factory Mutual Fire Insurance Companies, the National Board of Fire Underwriters, and the Bureau of Standards; also as Bur. Stds. Tech. Paper.

A series of 21 papers listed in the previous annual report have been issued as part of the Fourth Annual Report of the National Advisory Committee for Aeronautics.

The following papers will be published in the Fifth Annual Report of the National Advisory Committee for Aeronautics:

The Properties of Flat Plate Radiators (S. R. Parsons).

Properties of Fin and Tube Radiators (S. R. Parsons).

Properties of Whistling Radiators (S. R. Parsons).

Effect of Yaw on Radiators (S. R. Parsons).

Pressure Drop in Air Tubes of a Radiator (S. R. Parsons).

Comparison of Hector Fuel with Export Aviation Gasoline (H. C. Dickenson, V. R. Gage, and S. W. Sparrow).

Comparison of Alcogas Aviation Fuel with Export Aviation Fuel (V. R. Gage, S. W. Sparrow, and D. R. Harper).

4. OPTICS.

The work of the optical division includes the following principal lines of activity: Spectroscopy, devoted to radiation and absorption spectra, along with certain phases of qualitative and quantitative chemical analysis for which these are specially applicable, and the development of infra-red photography for astronomical observations and aviation purposes; polarimetry, devoted to investigations and tests involving measurements of polarized light and its application, especially in the testing, sandardization, and technology of sugar, including the supervision of the sugar laboratories of the Customs Service; colorimetry, concerned with the measurement of the factors which determine color, the optical transmissive and reflective properties of materials, and the color grading of light sources and materials; refractometry and optical instruments, interested chiefly in the performance and development of optical instruments and materials, including refractive indices and dispersion measurements; radiometry, which covers the more general field of radiation, determination of the fundamental constants of radiation, the development of radiometric methods and instruments, and the determination of the emissive, reflective, and absorptive properties of materials for thermal radiation; photographic technology, concerned with the investigation of photographic apparatus, testing of photographic materials and devices, standardization of testing methods, and general photographic investigations; interferometry, which makes use of the light wave as a standard unit for high precision length measurements and develops the application of interference methods. It includes also the optical investigation and measuring of the physical properties of dispersoids, such as smoke, water supplies, etc., and investigations in cooperation with the Engineer Corps of the Army on the conditions governing searchlight illumination, with especial reference to the testing and improving of searchlight mirrors and searchlamp performance.

SPECTROSCOPY.

Wave-Length Measurements.

Although emission spectra of the chemical elements have been the object of extensive and intensive study for over a century, practically none of them have as yet been completely described and their importance, both theoretical and practical, increases more rapidly than the knowledge of them is advanced. The significance of spectral series is beginning to be realized in connection with atomic models and radiation theory, and the actual possibilities in practical spectral analysis can be fully realized only after much more spectroscopic investigation.

Spectroscopic data are especially scarce and inaccurate for the yellow, red, and infra-red light waves to which the ordinary photographic materials are insensitive. With the use of photographic plates stained with photo-sensitizing dyes the Bureau has devoted itself to the longer wave portion of spectra for several years and has studied the arc spectra of most chemical elements to the limit set by our photographic methods and apparatus. During the past year it has issued Scientific Paper No. 372, containing measurements of wave lengths longer than 5,500 A in the arc spectra of seven elements—titanium, vanadium, chromium, manganese, tungsten, molybdenum, and uranium. Wave-length measurements in the yellow, red, and infra-red spectra of gold, silver, lead, zinc, tin, aluminum, cadmium, mercury, bismuth, and antimony were completed and collected for publication. Similar measurements have been made in the arc spectra of rare earths and uncommon elements like cerium, lanthanum, yttrium, erbium, holmium, neodymium, samarium, zirconium, columbium, gadolinium, europium, dysprosium, etc. These spectra are very complex and involve a large amount of labor to complete their description. All the wave-length measurements are made in International Angstrom units with the aid of working standards measured in the iron arc spectrum by interference methods. (See Sci. Paper 274.)

Low-Voltage Arcs.

Spectroscope work on low-voltage arcs as sources of light waves gives interesting information on the mechanism of radiation when

considered in connection with the resonance and ionizing potentials, which may be regarded as electronic energies required respectively to agitate and disrupt the atom. Scientific Paper No. 386, on "Atomic Theory and Low-Voltage Arcs in Cæsium Vapor," proves for the first time the existence of a single line spectrum under conditions where the atom is agitated but not ionized.

A New Microphotometer.

In connection with the investigation of spectra from low-voltage arcs, a micropyrometer was adapted for use as a microphotometer to measure the densities of spectral lines. This instrument has been described in Scientific Paper No. 385.

Spectroscopic Analysis.

Spectroscopic analyses of more than a hundred samples of materials were made in this laboratory during the past year. Some of these examinations were to test new analytical methods of chemistry and methods of purification. A large variety of materials were examined, among them being platinum, palladium, iridium, gold, silver, aluminum, calcium salts, welding wires, bronzes, tool steels, etc. At the request of the United States Treasury spectroscopic analyses of mint gold were made and spectroscopic methods of obtaining quantitative determinations of impurities in gold have received attention. Standard samples of pure gold alloyed with known amounts of silver, iron, and copper, which are the common impurities, have been made. Study of the spark spectra of such standard samples permits the interpretation of similar spectra of other samples, and yields a method of quantitative analysis which is rapid, especially sensitive to small amounts of impurities, and within certain limits satisfactorily reliable and accurate.

False Spectra From Diffraction Gratings.

The long photographic exposures required to extend observations of spectra in the infra-red revealed some new types of false spectra given by diffraction gratings. Gratings must be studied very carefully to separate the false lines from the real. Such a study was made of eight large concave diffraction gratings, all of which showed false spectra, which indicate periodic ruling errors of one or more types. A discussion of the results is to be published in the near future.

Spectrum Tubes.

Nearly 100 spectrum tubes filled with hydrogen, helium, neon, argon, oxygen, and mercury were made to serve as sources of monochromatic light for optical testing or wave-length measurement. Most of these tubes were distributed among astronomical observatories, universities, and industrial research laboratories, this Bureau being during the war period the chief source in this country of such apparatus.

Photosensitizing Dyes.

The importance of establishing a dye industry in this country has brought about a large amount of research on methods of making dyes of many kinds. Some of the dyes used in photography to

make emulsions sensitive to the longer waves of the spectrum were produced in this country soon after their importation from abroad was cut off by the war, and research work on these photosensitizing dyes is still in progress. Forty-three samples of dyes made by the Bureau of Chemistry of the Department of Agriculture were tested by the Bureau of Standards for their photosensitizing action. These samples include pinaverdols, which sensitize for green and yellow light; pinacyanols, sensitizing for orange and red; kryptocyanin for deep red; and dicyanin, which makes the photographic emulsion sensitive to red and infra-red light. Methods of using these dyes and the advantages derived from their use were described in a circular on "Color Sensitive Photographic Plates" and in a paper on "Dyes for Photographic Sensitizing" appearing in the Journal of the American Optical Society, May, 1920, and which will be published later in more complete form by the Bureau.

Aerial Photography.

Experiments in the use of color sensitive photographic plates for aerial photography have continued along the lines presented in detail in the annual report of 1919, pages 115 to 119. A series of interesting tests were made with a multiple lens camera loaned by the Army Air Service. This camera was fitted with four lenses containing ray filters and permitted the simultaneous exposure of four different kinds of plates for purposes of comparison. The penetration of haze by means of photography with red light was strikingly demonstrated by these experiments and the increase in speed of commercial panchromatic plates by treatment with ammonia was shown.

More recently some experiments have been made to discover just what part of the "characteristic curve" (relationship of developed density or blackness to the corresponding exposure) of a photographic plate is generally used in aerial photography. Various types of plates are exposed from airplanes in a calibrated camera and these plates are subsequently developed together with strips of similar plates exposed in a sensitometer. The comparison of densities in the aerial negative with densities in the sensitometer strips indicate some of the characteristics desirable in plates suitable for aerial photography. A report on these experiments is being prepared.

Tests of Photographic Emulsions.

In cooperation with the photographic laboratory of the Bureau the important characteristics (speed, development factor, contrast, fog, resolving power, color sensitivity, filter factor) of all photographic plates and films made in America have been investigated. These data are being collected in preparation of an atlas of photographic emulsions. This work is described in greater detail under "sensitometry" in the report on "Photographic Technology."

Laboratory for Special Photographic Investigations.

Plans and some preparations have been completed for the equipment of a special laboratory for investigations of photographic problems of scientific interest.

POLARIMETRY.

Developments in Polarimetric Work.

General recognition by the sugar industry of the value of the Bureau of Standards' contributions in polarimetry has resulted in a considerable broadening of the work in this field. The constantly increasing demand for the standardization of methods of analysis the standardization of technological processes and for accurate data on the fundamental constants of the sugars and their associate products has been met inadequately, but yet as fully as possible under existing conditions, by the setting aside of space and equipment and the securing of suitable experts to carry on the work. Necessarily, the process of accomplishing this is a slow one, and has consumed much time during the year.

The Rare Sugars.

The sugar group includes a relatively large number of substances each of which, in a physical and chemical sense, is a true sugar. It is only by means of the systematic study of the whole group that progress has been made in determining the true chemical composition of the common sugars. Even at present the exact chemical formula of cane sugar is in a state of some uncertainty.

Many members of this group have a very limited distribution in nature; many occur only as constituents of more complex chemical individuals, and many are of common occurrence, but are difficult to isolate and purify.

The chemistry of each one of these sugars contributes by analogy, or direct deduction, to the chemistry of the whole group. In a pure state, they have a variety of uses, the most important of which is at present the differentiation of pathogenic bacteria. For this purpose the sugar must must be in a state of high purity. In order to ascertain the degree of purity, it is necessary to know accurately the properties of the pure substance. With this end in view, the Bureau has undertaken to determine the optical rotation (polariscopic effect), reducing power, and such other properties as are required to form complete specifications for a pure product.

The demand for the rare sugars and their associated compounds for use in various scientific fields and in medicine has greatly increased during the past year. The complexity of modern civilized life is such that a substance of scientific interest only to-day frequently becomes of commercial importance to-morrow. This fact has been exemplified in a number of instances in the rare-sugar industry. There are now a number of large concerns producing these substances. Their product is often necessarily impure, but it is the best that can be done with the available scientific data. Formerly, the only available source of supply for these materials was the German-made product. As a result of the development of the industry in the United States, importation has not only practically ceased, but a very considerable export business has developed, particularly with the South American countries. The Bureau has assisted the American manufacturer in every way possible. The necessity of obtaining these materials in pure form for the War De-

partment and for the medical profession has necessitated the hurried preparation of indispensable scientific data on certain of the sugars. At the same time, plans have been completed for a section devoted to the development of the necessary scientific constants and other data needed in this field. The results obtained have been most encouraging.

During the year, a number of these rare sugars have been submitted by the War Department for test. This test necessitated a purification and determination of the properties of each substance, since no reliable data exist. The tests showed that but few of the sugars were highly purified. Many were so impure that they were rather of the nature of crude substances. Inasmuch as the Medical Department of the Army had already completed important bacteriological work on these sugars, the urgency of obtaining complete specifications is apparent.

Among the sugars studied are arabinose, raffinose, xylose, rhamnose, melibiose, dulcite, and mannite.

Optical Properties of Oils.

Oils, whether mineral, fatty, or essential, are extremely complicated mixtures, and as such are very liable to adulteration. It has been found that certain optical tests, among which the polarimetric tests are important, are very useful in determining the composition and purity of these substances. Many oils are naturally active; that is, they produce a rotation of plane polarized light, to a more or less extent, while all become active to varying degrees in a magnetic field, and are double refracting in an electric field. Complete data on these optical effects for different colors of light should lead to the formulation of an adequate theory which would be of great aid in determining the composition and molecular structure of oils. These results, taken in conjunction with other physical and chemical data, should also be very valuable in determining the suitability of any of the oils for commercial purposes, such as foods, fuels, paints, lubricants, etc.

The polarimetric study of oils is a new field which the Bureau has entered, owing to the continued demand for scientific data. Already several of the large oil consuming companies are using these physical tests, owing to the fact that, even in their present crude form, they are the only means available for grading crude oils for certain purposes. Considerable work has been done on preliminary investigations and in collecting and coordinating the data at present available on this subject, as well as in devising methods and preparing apparatus for the testing and further investigation of all commercial oils.

Testing of Quartz Control Plates.

A plate of crystalline quartz, cut perpendicular to the axis of the crystal, has the same influence on the direction of the plane of vibration of a light wave as a sugar solution. Science has taken advantage of this fortunate circumstance to provide a positive and unchangeable device in the form of the quartz control plate for checking the accuracy of saccharimeters. The complicated

saccharimeter may easily get out of adjustment, thereby rendering uncertain the test of a sugar. Any inaccuracies due to this condition are wholly avoided by placing a quartz control plate in the instrument and comparing the reading with the accepted value of the plate. These plates are thus of fundamental importance throughout the sugar industry and in all scientific laboratories. During the year, 29 were tested, 10 of which were for European concerns; the others for various sugar companies. Two were rejected as being totally unfit for saccharimetric use. Several were improperly mounted in wax. These were removed from their original mounts and remounted in loose metal holders so as to comply with the Bureau's specifications.

On account of the difficulty of obtaining control plates, and with the idea of being of the greatest possible assistance to the sugar industry, the Bureau has, whenever feasible, undertaken the remounting and testing of improperly mounted plates. This procedure serves to make reliable many plates which would otherwise be unfit for accurate work. On account of the fact that many of the plates now being received are of unknown origin, it is more than ever important that they be critically examined for defects. As an aid in accomplishing this, apparatus has been set up for testing the planeness and parallelism of the plates and measuring the "axis error," i. e., the angle between the crystallographic or optic axis of the plate and the normal to the plate. These tests are made in addition to the usual tests for homogeneity and sensitivity in the polariscope.

Advantage has been taken of the Bureau's wide experience to draw up a set of preliminary specifications as a guide to manufacturers in producing first-quality control plates.

An important service is thereby being rendered the entire sugar industry, as it will render available a supply of uniformly good plates of American manufacture.

Acidity Measurements on Refined Sugars.

A complete description of the properties of a sugar product should include a measurement of its "reaction." By "reaction" is meant the degree of acidity or alkalinity of the sugar when dissolved in pure neutral water. An accurate method of determining this property of refined sugars has never been available. This condition has persisted in defiance of the generally recognized fact that the acidity was probably affecting the usefulness of the sugar for many purposes to a profound degree. Measurements were made on about 150 samples of commercial white sugars. A colorimetric method which has been extensively developed elsewhere has been adapted to this purpose. A number of indicators (organic substances whose colors are extremely sensitive to the reaction of a liquid) have been developed and their colors related exactly to the reaction in question. Of these indicators, seven or eight of which have been found to cover about the whole range of reaction of naturally occurring substances, two were found sufficient to indicate the reactions of white sugars. Some sugars were found to be acid, the greater number approximately neutral, and some alkaline.

Those which were found to be acid or alkaline were reduced (titrated) to exact neutrality, and the quantity of reagent necessary to produce neutralization carefully measured. Striking differences were observed. Many substances, having the same acidity, required very different quantities of reagent to produce neutrality. This fact indicates variations in the nature of the impurities and suggests the presence of "buffer" substances, i. e., substances which resist a change in reaction.

While the actual magnitude of the alkaline or acid substances amount to but a few ten-thousandths of 1 per cent, the variations in their quantities exert fundamental effects on sugars when used for certain manufacturing processes. While it is too early to predict the results of this study, it is possible that an intimate relation exists between the reaction and the "strength" of the sugar. "Strength" is a term used by candy manufacturers to designate the behavior of sugar when boiled at a high temperature. The exact definition of this term and its correlation with other properties must await further study.

100° Point of the Saccharimeter Scale.

In the previous report attention was directed to the fact that the Bureau had inaugurated the policy of standardizing all saccharimeters and quartz control plates on the new value of the 100° point. The investigation covering the determination of this fundamental constant, on the value of which all sugar throughout the world is bought and sold, has been discussed in previous reports. Owing to the fact that the error discovered in this constant was a relatively large one, the Bureau delayed putting the new value into effect in the hope that international agreement might be secured. When it seemed impossible to bring this about, the new value was put into effect by the Customs Service. The wisdom of this procedure has been amply proven by the fact that the developments in international scientific relations have tended to postpone indefinitely any agreement on this important matter. Vigorous efforts were made during the past year by many interested parties to bring about a session of the International Sugar Commission to discuss the matter, but without result.

United States Customs Laboratories.

The modern chemical laboratory which the Bureau designed for the Customs Service at Boston and which contains a number of innovations has now been in operation for over a year with most satisfactory results. It has not been found necessary to modify either the design or the equipment, and it is being used as a model laboratory throughout the service.

An opportunity similar to that at Boston was developed by the remodeling of the United States customhouse at New Orleans. Advantage was taken of this opportunity to provide suitable quarters at that port for the installation of a modern customs laboratory similar to the Boston laboratory. Detailed specifications and plans drawn up by the Bureau have resulted in giving the port of New Orleans a laboratory replete with all modern facilities. The importance of

these laboratories to the Treasury Department is shown by the fact that over 60 per cent of all the revenue from customs is collected either directly or indirectly through the customs laboratories.

Sugar and Molasses at the Smaller Ports.

Large as have been the importations of sugar and molasses through the small southern ports in recent years, a still further volume was handled during the past 12 months. Owing to the fact that it is impracticable for the Customs Service to maintain the necessary equipment and testing facilities at any except the large ports of entry, it was found necessary to devise methods of transmitting samples from small ports to the larger ones for testing. These methods devised by the Bureau of Standards for this work have proven satisfactory and will be continued indefinitely.

Definitions and Specifications of Commercial Sugars.

Work on the problem of preparing standard definitions and specifications for refined sugars has been continued uninterrupted. The investigation has developed into a more extensive one than was anticipated. Over 250 samples have been systematically studied by means of chemical analysis, size of crystals, moisture content, color, and other chemical and physical properties. The results so far obtained have proven interesting and valuable. The data are so extensive that it is planned to publish them as a separate circular, and it is hoped will permit of accurately preparing a scientific definition of each of the necessary grades of commercial sugars.

At the present time, there are about 40 varieties of sugar on the American market that are suitable for direct consumption. The trade names give little or no indication of the character of the sugar. It is believed that the accurate classification, for which the Bureau is striving, will be of great benefit to both the consuming public and the manufacturer.

Color of Sugars and Sirup.

An important factor in the grading and standardization of sugars and sirups is a definite statement of the color. The value of these commodities depends in no inconsiderable degree upon this factor. Unfortunately, a great deal of confusion has always existed, and no strictly accurate and scientific method has been made sufficiently simple to be practical for routine industrial use. During the year the polarimetry and colorimetry sections of the Bureau have developed a simplified method which gives accurate data on a scientific basis and a colorimeter has been constructed. It is applicable to the grading of raw sugars and sirups and many other materials which are normally in a liquid state or can be feasibly examined in this state by fusing or dissolving.

This method is not satisfactory for the examination of white granulated sugars, both because other factors beside the color enter into the appearance of the crystals, and because making a solution of the sugar is too tedious. For this purpose no method has yet been made to equal in sensitiveness and accuracy the viewing of the sample to be graded under standard illumination beside a series of arbitrarily

graded samples covering the range desired. The Bureau is now working on a method for the direct examination of white sugar, which will indicate the color-grade on a rational scale of reference.

Preparation of Levulose.

Levulose is one of the most abundant of the sugars; the great difficulty of isolating and purifying it make it one of the most costly sugars on the market. Owing to the fact that it is the sweetest of all sugars, that it is easily digestible, that it is abundant, and that it has many uses in bacteriological and chemical laboratories, its production in quantity would make it an important commercial and scientific commodity.

The Bureau has experimented with the method of separation of levulose from invert sugar of which it is a constituent. This separation, which is accomplished by means of lime at low temperatures, has been studied with the purpose of finding the optimum conditions of concentration of sugar and lime. Under favorable conditions, a yield of 85 per cent has been obtained in small-scale experiments. The influence of the other constituent of invert sugar, namely, dextrose, has been ascertained. About 10 pounds of levulose has been prepared for further investigation.

Work is now in progress on its preparation from other sources of supply. The combined results so far obtained in this important scientific and commercial problem indicate the early development of a method of production which will make levulose available in quantities for all purposes and at a materially reduced cost.

Analysis of Sugar Mixtures.

The investigation in this subject, including the redetermination of the Clerget constant, has been completed. Impure sugar products always contain optically active substances which influence the reading of the polariscope in much the same manner as sugar itself. Therefore, a single reading of the polariscope is merely the resultant effect of all the substances present, and consequently does not indicate the true percentage of sugar. In order to effect the analysis of sucrose, it is necessary to supplement the first reading of the polariscope or direct polarization by a second observation in which the rotation (i. e., polariscopic effect) of the impurities is maintained unaltered, but in which all of the sucrose has been changed by the action of acids to invert sugar. The latter is a mixture of two simpler sugars which has a rotation in the opposite direction from that of sucrose. The total change in rotation of pure sucrose is 133.25° at 20° C. This value is known as the Clerget constant and is of fundamental importance in sugar analysis. The previously used value of 132.66° was thus found to be in error by nearly 0.6°.

In using this method of analysis, certain precautions must be taken to guard against an error arising from the lack of constancy of the rotation of impurities. Thus the investigation has shown that if invert sugar is present in the original sample taken for analysis, a weight of salt equal in weight to the acid used for inverting the sugar must be added to prevent a change in the rotation of the original invert sugar. This, however, changes the value of the Clerget constant by an amount that was accurately determined. Similarly the

presence of other classes of impurities has necessitated minor modifications in the analytical procedure, each of which has required an accurate determination of the value of the Clerget constant.

The investigation has made it possible to express by a simple formula the value of the constant under a wide range of conditions and thus to select from current literature those determinations which are accurate. In this manner a number of recent determinations of the Clerget constant, made under widely varying conditions, were correlated within the limits of accuracy of the measurement. Previous to the establishment of this formula these values were isolated empirical quantities, having little apparent relation to each other.

Raffinose in Beet-Sugar Products.

In continuation of the work on the analysis of sugar mixtures, satisfactory progress has been made in extending the methods developed to the determination of sucrose in the presence of other disturbing impurities. The most urgent need is that of the estimation of sucrose in beet products which contain "raffinose." "Raffinose" in beet products, as determined at present, includes a number of substances to which is assigned a rotary power equal to that of pure raffinose, a pure sugar occurring in beet juices. It is well known that but a portion of these substances are truly raffinose, but no method of distinguishing them is as yet known. Consequently, the Clerget analysis of beet products does not represent correctly either the true sucrose or the true raffinose content.

Picnometer for Viscous Materials.

Accurate determination of the density of a viscous liquid has long been a difficult problem. The major difficulty lies in the large quantities of air or other gases, which, owing to the high viscosity of the liquid, can not be liberated except by heating. For many substances, such as molasses, this procedure is not permissible. The Bureau has brought about during the past year an improvement in existing conditions for density determinations by designing and perfecting a picnometer, through the use of which errors due to included air and evaporation are to a very great extent eliminated. Increased accuracy in this work, which is important both for scientific and commercial purposes, has been attained. The results of the investigation including a description of the device were published.

Testing of Molasses.

The Bureau continued to act as referee between buyers and sellers in the polariscopic analysis of molasses. Practically all molasses for manufacturing purposes is bought on the basis of sugar content and density. A number of manufacturers specify in their contracts that the Bureau shall act as referee in the event that a controversy arise. During the year, the Bureau acted as referee in 11 cases where large sums of money were involved. By using the Bureau's corrected value of the Clerget divisor it has been found possible to attain a higher accuracy in the estimation of the sucrose content of molasses. The methods available for the determination of density are still under investigation. One applicable to commercial analysis has been devised which gives satisfactory agreement with the method using the picnometer, previously described.

Standardization of Sugar Manufacture.

Although the manufacture of sugar from the juices of the beet and cane has been carried out for a great many years, and very few changes have recently been made in the general methods of the manufacture of either of these kinds of sugar, yet there is great diversity of opinion and practice as to the details of almost every process involved. This uncertainty is due, first, to a lack of definite scientific data, especially that pertaining to the physical chemistry involved; and, second, to the fact that there has been no central bureau with facilities for the study and adequate coordination of the information already acquired in various ways by manufacturers and others. In recent years, corn sugar or dextrose, and still more recently, malt sugar or maltose, are appearing in large tonnages.

The need for standardization is now being felt by the whole sugar industry. The great corporations operating chains of factories or plantations have done much to standardize methods within their own organizations, and some even have their own well-organized research departments. They are, however, as insistent as the small manufacturer in their demands on the Bureau for research and standardization, because there is still left a vast field which only a central, unbiased, well-equipped agency, such as the Bureau, can cover satisfactorily.

Molasses Formation.

The juices and sirups, from which all kinds of commercial sugars are made, consist, in each case, of a complex solution containing the sugar in question and a large number of impurities. Some of the sugar is removed by crystallization, leaving most of the impurities still in solution. This process may be repeated several times, but before all the sugar is removed a point will be reached where sugar will no longer crystallize, because it is held in solution by the impurities. This residue is molasses. Some impurities decrease the quantity of sugar retained in the molasses, but most of them increase it. Small differences in the details of some of the processes used in the manufacture are known to influence greatly, on the one hand, the amount of impurities introduced from outside sources as well as those extracted with the juice; and, on the other, the amount of impurities removed in the various purifying treatments before crystallization is begun. The solubility curves of several sugar-salt systems have already been worked out. This investigation covers a wide field and is of economic importance. Several parts of the work are already outlined and under way.

Beet and Cane Molasses.

In most beet-sugar factories the residual molasses from the crystallization processes is treated chemically to separate the sugar from the accompanying impurities which keep the sugar in solution. In factories located in the Middle West and northern portions of the United States the process in use results in the accumulation of a substance which is optically active and forms solutions of great viscosity, thus interfering with chemical control of the processes on the one hand, and with the actual process of crystallization on the other. The Bureau is carrying out work on this substance with

three principal objects in view: To develop, first, a method of analysis which will avoid or eliminate the interference of this substance in the polarization of sugar; second, a method of minimizing its deleterious effect on the crystallization of sugar, and, third, a possible method of minimizing or avoiding its formation and accumulation. Considerable progress has already been made.

Decolorizing Carbons.

One of the most important recent developments in the cane-sugar industry is the general movement for the production of "direct-consumption" sugars; that is, sugars which are fit for consumption without further refining. A most important factor in this development promises to be the use of the new decolorizing carbons, of which a number have appeared upon the market, and for which patents for many more have been granted. A detailed study for the standardization of these substances is well under way. The research will include other clarifying agents, and promises to be of value also in the production of new types of beet sugar and in the manufacture of corn and malt sugars.

Gradation of Sugars by Sieve Analysis.

The Bureau has at its disposal over 225 samples of the various sugars submitted by the principal producers in the United States. A careful comparative examination of these sugars shows the lack of a systematic method of grading by the size of the crystal. For the elimination of confusion, such as occurs between the producer and the consumer, the Bureau has undertaken a systematic study of the gradation of sugars by screen analysis. As a result of the data already obtained, specifications will be submitted which will materially help to define the sugars now sold on the American market, and also help in the advancement of the standardization of the sugar industry.

Diffusion in Beet-Sugar Production.

In beet-sugar factories it is possible for the quantity of impurities removed from the beets along with the sugar to vary greatly with the method of diffusion. The effects of the various factors involved are not well understood, and certain lines of work are now under way to elucidate the principles underlying each effect, and thus establish a standard practice which can be applied to all conditions. This work is of fundamental importance to the beet-sugar industry, and it is expected to prove of considerable value in cane-sugar practice as well.

Production of Mannite.

The production of d-mannite of high purity from crude manna has been continued, with the twofold object of obtaining needed scientific data on this important sugar and of creating a sufficient supply to meet the needs of the medical service of the Army. Both objects have been attained. Extensive experiments have been conducted on the purification of mannite, using a new commercial vegetable carbon as the decolorizing agent. Solutions of high purity were obtained from which excellent yields of white mannite were taken. In addition, other methods of decolorizing and purifying the

crude liquors have been studied. An experimental plant has also been designed which will be suitable for the purification of mannite and other materials.

A study of the optical rotation of mannite is being made with the view of defining specifications of purity for this material.

Society of Sugar Chemists and Technologists.

Owing to the fact that the sugar industry of the United States is the most diverse of any nation, the necessity for some organization which would bring together the large numbers of scientific and technical men in its various phases has long been especially acute. Under such circumstances the interchange of ideas resulting from such an association benefits to an unusual degree not only the individual members but also the industry as a whole. Because of this situation, and by request, the Bureau has for some time been rendering its assistance in every way possible to the formation of a society of American sugar chemists and technologists. In view of the fact that many persons desired to attend the meetings of the American Chemical Society and for other reasons, it was finally decided that the proposed society should organize as a section of the American Chemical Society. The initial meeting was held at St. Louis. Over 60 sugar chemists and technologists were present. The members represented every part of the United States geographically and every phase of the sugar industry, including the manufacturers of the rare sugars, glucose, and the various materials used in the production of sugar. The regular program of the meeting included, among other things, 15 scientific and technological papers. Previous experience has demonstrated that where it is possible for such an organization as this to be perfected, it invariably opens up new channels which make it easier for the Bureau to extend its usefulness and cooperation with the industry.

Composition of Sirup.

A considerable portion of the cane sugar produced in this country is distributed in the form of sirup for direct consumption. The problem of producing a stable sirup has long been a fundamental one in the sirup industry. A saturated solution of pure sugar contains about 67 per cent of sugar. Such a solution is too dilute for a useful product and moreover is capable of fermentation, and therefore likely to spoil. If more concentrated, it eventually deposits sugar crystals in the container. This investigation has shown that if the sugar is partially inverted, the sirup may contain as much as 79 per cent of total sugars, and still remain undersaturated. Such a sirup, in addition to remaining indefinitely in a state of solution, resists the action of fermenting microorganisms. By means of extensive solubility determinations, the exact composition of the mixture which shall have the maximum content of dissolved substance has been determined.

There are in existence a number of methods of producing partial inversion. The Bureau has discovered that it may be cheaply and efficiently accomplished by adding a relatively minute quantity of hydrochloric acid. The exact conditions of time and temperature are described in a publication now in preparation. A number of important by-products have been obtained in carrying out this work.

Among them may be mentioned an accurate measurement of the density of invert sugar solutions, the volume of the contraction and the change of viscosity which result from the inversion of sugar. The facts developed in this investigation have been recognized as being of importance to the sirup industry and the Bureau has made one application on a factory scale at the request of the manufacturer.

Crystallization of Sugar.

Most high-grade chemicals are purified by a process of fractional crystallization. White granulated cane or beet sugar, as it ordinarily appears on the market, is of a purity equal to that of most of the "chemically pure" reagents used by the chemist. It, too, is prepared by a process of fractional crystallization in quantities several times greater than any other chemically pure commodity. This process is therefore probably used more extensively in the preparation of sugar than in any other manufacturing business. Nevertheless, a great deal remains to be learned about crystallization, and particularly about fractional crystallization, under the various conditions which are encountered in sugar-making. A thorough investigation of this subject has been undertaken by the Bureau, and when it is finished it should be of economic value to the country.

Purification of Sugars.

During the year an important research on the speed of falling of solid particles through fluids has been completed. It has applications in many processes of clarification and filtration which are used, or have been proposed for use, in the several branches of the sugar industry. Two specific illustrations are the processes of thickening by settling and centrifugation, and of clarification of juices (including fruit juices) by centrifugation. The results obtained in this investigation promise to be of importance in the study of ballistics, quite outside the sugar industry. This work is now being extended to cover certain colloidal phenomena.

A study of the principles involved in the ordinary processes of filtration has been outlined and this will be applied to the newer types of apparatus as well as to the older ones, with the object of standardizing certain types to fit particular purposes and conditions of service. Various manufacturers have offered to make up and lend apparatus for these tests. One phase of this work includes a study of filter fabrics and their application to the various types of filters.

Candy Test for Sugar.

One of the most obscure phenomena exhibited by sugars has been the wide range of variability of their suitableness for candy-making purposes. Certain sugars will give excellent results, whereas the use of similar sugars will often give a product that is not satisfactory. A reliable method of differentiation of sugars for manufacturing purposes is urgently needed. The problem has been studied in connection with the preparation of definitions and specifications for commercial sugars. The most definite result has been in the partial development of a candy test which has already attained a considerable degree of precision, indicating the presence of minute quantities of certain impurities in sugar which enhance or decrease its value for candy making. This test is being further developed to

increase its intrinsic value and for the purpose of correlating with it shorter and simpler tests which may possibly be substituted to a considerable extent.

Official Baumé Scale.

At the annual meeting of the Association of Official Agricultural Chemists, representing each State in the Union, the Baumé scale proposed by the Bureau was recommended for adoption and action was taken to discard all other Baumé scales in the official publication of methods of analysis. The importance of this step arises from the fact that there are about 20 scales now in use and that the Baumé density is capable of a varied interpretation. With the single national definition of Baumé density at the standard temperature of 20° C., these differences should disappear.

Supplies for Customs Laboratories.

The difficulties incidental to obtaining sufficient supplies for scientific laboratories during the war have continued throughout the year. This condition has notably affected the operation of the United States Customs laboratories. Necessarily, many of their supplies, as well as equipment, must be purchased under rigid specifications in order to insure the accuracy necessary in precision work. The lack of suitable supplies has been further aggravated by the uncertain volume of importations. In order to overcome this condition, the Bureau has succeeded, through cooperation with the Treasury Department, in securing a reserve stock of all supplies requiring a Bureau test for acceptance and has set aside a storeroom in which these supplies can be held. A sudden shortage at any port can therefore be relieved by immediate shipment, and delay incidental to appraisement of imported merchandise thereby prevented. Supplies thus far accumulated include volumetric flasks, polariscopes, polariscope tubes, polariscope tube cover glasses, bichromate absorption cells, etc. It is planned to gradually extend this procedure to cover many other needed precision supplies. Through the efforts of the Bureau a large supply of polariscope tubes have been obtained and tested. All tubes in use at the various ports have been replaced with new ones and the old tubes returned to the Bureau for test. The previous practice has been when a test tube was placed in the Customs Service, after it had been standardized at the Bureau, to permit it to remain there until discarded. The wisdom of returning the tubes annually to the Bureau to be tested was shown by the numerous inaccuracies found in the tubes which had been in the service but a little over a year. It has also been found possible to have the manufacturer renew many of these tubes, thereby saving a considerable sum annually to the Government. The procedure of the Bureau in this matter is an excellent illustration of what can be accomplished by cooperative operation between different departments.

Cooperation with Customs Laboratories.

The work incidental to assisting the Treasury Department in the maintenance and operation of its customs laboratories has been continued with excellent results. The abnormal situation which has

prevailed for some months throughout the sugar industry has resulted in the heaviest importations of raw sugars the United States has ever known. This is attributable not only to an increased domestic consumption, but also to the fact that large quantities of raw sugars have been refined in this country for European consumption. This situation has necessarily created much additional work for the Bureau. Throughout this abnormal situation the high percentage of accuracy of the quantities of sugar tests has been successfully maintained. In this work 1,521 exchange samples of raw sugar for controlling the work of the sugar laboratories at the customs ports were tested. Approximately 50 per cent were direct polariscopic determinations for the quantity of sucrose present, and the remainder were tested for the percentage of moisture in addition to sucrose content.

Natural Rotation of Quartz at High Temperatures.

The investigation of the natural rotation of light by crystalline quartz at high temperatures has been continued. As the temperature of a quartz crystal rises, the magnitude of the angular rotation of the plane of polarization of light passing through the crystal increases rapidly as the temperature approaches the recrystallization point at 573.3° C. As this point is approached there occurs a most profound change in all the physical properties of the crystal. Just below the inversion point a slight change in temperature causes a very large change in the rotation. The curve expressing the change of rotation with temperature has been found to be practically a straight line, almost parallel to the temperature axis from the inversion point at 573.3° C. to about 1,500° C. A molybdenum-wound furnace has been constructed with which it is hoped to push the observations well above 1,500° C., perhaps to the melting point of the quartz crystal.

Below the inversion point the law has been developed that the relative change in the rotation with change of temperature is practically the same, no matter what may be the color of the light passed through the crystal. The so-called rotation dispersion has therefore been proven to be the same for all wave lengths at all temperatures up to the inversion point.

From the data obtained an equation has been determined which fits the observation for temperatures up to the inversion point. This equation can be made to express the change in rotation with temperature for any wave length by multiplying it by an appropriate constant, i. e., the initial rotation of the quartz for that particular wave length. There is, however, a slight deviation (of the order of a few hundredths of a degree) of some of the observed values near the inversion point from those calculated from the equation. Subsequent experiments will show whether this is due to inherent experimental error or is a true deviation from the law of constant dispersion at all temperatures. As stated in last year's report, the Bureau's polarimetric measurements are the first precision measurements ever made at high temperatures.

Adjustment and Standardization of Polariscopes.

The work of adjusting and standardizing polariscopes and saccharimeters has been continued. The Bureau's facilities have been

taxed to the utmost to handle all the instruments submitted. The sugar industry, as well as educational and research institutions, have been unable for some years to obtain an adequate supply of new polariscopes. Until recently no new instruments could be obtained. Owing to the sudden expansion of the sugar industry and the impossibility of obtaining additional instruments, it became necessary to resort to the use of instruments which had been discarded. Many of these have a different basis of calibration from those of newer types. The Bureau has constantly been consulted in regard to the use of these instruments and has been able to render important services. Another class of discarded instruments are modern types of excellent design for manufacturers' and refiners' use, which, however, have been rendered useless through wear or because the optical parts are out of adjustment.

In connection with the work of rendering these instruments serviceable, a number of related problems have come up and been solved. As a result of this work, the Bureau has been able to render an important service to the sugar industry and the public. Many letters of commendation have been received. During the year 55 instruments were standardized. After adjustment the scales of all polariscopes submitted were carefully compared with the official standards of the Bureau and certificates issued showing the corrections necessary to be added to the scale readings to give the true rotation in sugar degrees, based on the widely accepted Bureau of Standards determination of the international sugar scale.

The Natural and Magnetic Rotations and Rotation-Dispersions of Sugars.

One of the fundamental properties of matter is its power when placed in a strong magnetic field to so modify the vibrations which constitute light that if a beam of plane polarized light is passed through the substance in a direction parallel to the magnetic field a rotation of the plane of polarization will take place. The rotation is constant for each substance and is different for different substances, so that the magnetic rotation of a substance constitutes one of its characteristic physical properties. Measurements have been undertaken on the natural and magnetic rotations of various sugar solutions, more especially sucrose, dextrose, and levulose, for various wave lengths of light. The purpose of this investigation is twofold—first, to accurately measure and record this additional characteristic physical property so that it will be available for general use, and, secondly, to coordinate the data obtained with other known chemical and physical properties in an effort to solve a number of problems for which a solution has long been demanded.

Light Filters.

The standard light filter for saccharimeters as adopted by the International Sugar Commission is a layer 1.5 centimeters thick of a 6 per cent potassium bichromate solution. This filter has the disadvantages inherent in a solution. It is awkward to handle, the cells are not permanent, and if inclosed in the instrument the leakage may damage the optical parts. The solution in time becomes dirty and has to be renewed. It would be a decided improvement if a perma-

nent filter, such as a colored glass, could be used in place of the solution. A glass for this purpose should have the same or approximately the same spectral transmission as the bichromate solution, so as not to introduce any error in the saccharimetric readings. With the object of finding such a glass, several samples have been examined and an endeavor is being made to obtain specimens from as many sources as possible.

The question of a light filter for saccharimeters is an important one, and before making any change from the bichromate filter, as prescribed by the International Sugar Commission, the Bureau must have conclusive experimental evidence that the change will not affect the saccharimetric readings.

Standard Samples.

During the past year 138 samples of sucrose and 31 samples of dextrose were distributed. These materials are used principally for industrial and scientific purposes. There is a steady increase in the demand upon the Bureau for standard samples of the sugars.

Polarimetric Testing.

Large numbers of cover glasses for polariscope tubes were tested for optical homogeneity and for absence of optical activity. All glasses tested for the Customs Service were of American manufacture. In addition considerable numbers were tested for private concerns.

Polarimetric Measurement of Strain in Glass.

Practically all glasses, unless carefully annealed, are under great strain, due to certain parts cooling in advance of other parts. These strains, incorporated in the glasses during their manufacture, are most easily detected by a light phenomenon which they exhibit, technically known as double refraction. The character of the annealing which optical glass has received is of great importance in the manufacture of optical instruments. The only practical method of testing glass for the sufficiency of its annealing for optical and other purposes is to subject it to a polarimetric test, which determines its double refraction. In collaboration with the pyrometry section, methods of testing glass very accurately for this phenomenon have been adopted, and tests are being made of the relative degree of annealing obtained by various methods of treatment. A study of the stress distribution in glass pieces differently treated and having different geometrical shapes is also being carried on in order to compare the experimental results with the distribution to be expected from certain theoretical considerations. It was also undertaken to determine any relation which may exist between the stress distribution and the fitness of the glass for optical purposes.

The object of another investigation on which some preliminary work has been done is to increase the knowledge of the relationship existing between the stresses in glass and the double refraction produced by them. The ultimate purpose of these various investigations, when sufficient data have been obtained, is to establish a more uniform standardization for the degree of annealing of glass, especially that intended for optical purposes, which shall take the place of the arbitrary standards now in use. Several manuscripts covering the results obtained in this investigation have been prepared.

Commercial Process for Manufacturing Pure Dextrose.

Dextrose or glucose is the sugar which results from a chemical treatment of cornstarch. It exists on the market as a sirup (corn sirup) or as a light brown aggregate of round solid grains having a purity of about 94 per cent. The Bureau has shown that a pure white dextrose may be obtained by crystallization from a water solution and may easily be separated from the mother liquor by using a centrifugal machine. Previous methods for the preparation of the pure substance have demanded the use of alcoholic solvents. The improved laboratory process obviously would permit of operation on a large scale and at reduced cost. A member of the Bureau's staff was accordingly sent to a large glucose manufacturing company to apply the process on a commercial scale of operation. Two processes were investigated. In the one which met with almost immediate success, the "converted" starch liquor was boiled in a vacuum until concentrated to 42° Baumé and was then dropped into a crystallizer. It was then innoculated with crystals of pure dextrose and agitated until the crystallization was complete. The Bureau has found that at a temperature in the neighborhood of 35° C. the crystalline form of dextrose changes. Below that temperature the substance contains water of crystallization; above, it is anhydrous. Consequently, it was found necessary to keep the crystal mass above 35° C. in order to prevent the formation of crystals of irregular sizes which prevent efficient work with the centrifugal machines.

When the growth was finished, the crystal mass was easily separated from the mother liquor and a satisfactory yield of pure crystalline dextrose was obtained, having the whiteness and purity of commercial cane sugar.

The second and more difficult process was that of accomplishing the crystal formation directly in the vacuum pan. While this was not brought to the same stage as the first process, enough was accomplished to show that the process was a feasible one.

In carrying this investigation to a successful conclusion, the Bureau has virtually created a new industry of great magnitude. There are innumerable uses for glucose, or, as it is more commonly called, corn sugar. The fact that this material has never been available in pure form at a reasonable cost has prevented its use on a large scale. The process developed is very similar to that used in the production of the best grades of granulated sugar, and the glucose secured by the new process is a beautiful, fine white crystal. The cost of production is actually less than the cost of producing the round, solid, brown material which was formerly produced. The magnitude of the commercial possibilities of the new sugar is shown by the fact that one of the largest corporations in the country requested the Bureau to design a large scale experimental plant, costing approximately one-half million dollars. This has been done and the plant is now practically completed.

New Cadmium Vapor Arc Lamp for Polariscopic Uses.

For some years numerous experiments have been carried out by a number of investigators with the object of obtaining a cadmium vapor lamp similar to the mercury vapor lamp. This has been done because of the necessity of securing a stable monochromatic red light

source of high intensity. When pure cadmium is distilled into the quartz lamp and freezes the metal adheres to the silica with such tenacity as to either crack the lamp or peel strips of the silica from the walls. If such a lamp be filled with a cadmium mercury alloy, the cadmium spectrum appears but faintly, and the position of its principal lines in the spectrum with respect to the mercury lines is such that spectrum filtration with a wide slit is impracticable. The lack of intensity in the cadmium spectrum is due to the fact that its vapor pressure is relatively low compared with that of mercury.

Upon investigating this problem, the Bureau discovered that the metal gallium would readily alloy with cadmium, and that a very small quantity, less than 1 per cent, was sufficient to radically change the character of the cadmium and greatly reduce its tensile strength. All breakage of the lamp was eliminated. In using this alloy in a quartz lamp the cadmium spectrum is obtained with great brilliancy and purity. Although gallium melts at approximately 30° C., its boiling point is above 1,600° C., and its vapor pressure is so low that the spectrum of gallium is practically absent, the cadmium vapor acting as the carrier of the electric energy. A lamp of this type, using lead seals to render the electrodes proof against leakage, can be operated continuously with no variation in the high intensity of the cadmium lines and appears to have an indefinite life.

COLORIMETRY.

This section is concerned with the measurement of the physical properties which serve to specify the sensation called "color." As the ordinary stimulus of color sensation is light, colorimetry deals with measurements relating to light, and defines the color of a substance as the color produced by the light transmitted or reflected by the substance under prescribed conditions. The color of light is determined by its frequencies or wave lengths, the relative intensities of the component frequencies and their total intensity.

The investigations of the colorimetry section are closely related to those of other sections of the Bureau, such as photometry, radiometry, and photography, and its methods find practical application in chemistry, ceramics, pyrometry, and in the testing of textiles, paper, paints, dyes, oils, and other materials, and in the specifications and regulations governing the use of railway and other signals and eye-protective glasses.

General Summary of the Year's Progress in Colorimetry.

Material progress of a satisfactory nature has been made in three major or general problems in colorimetry and the measurement of transmission and reflection of radiant power, namely: The standardization of the nomenclature of chromatics and colorimetry; improvement of methods and standardization of routine practice in spectrophotometry and in ultra-violet and short wave-length infra-red radiometry; and in the application of rotatory dispersion to photometry, colorimetry, and pyrometry.

Many special investigations have been conducted during the year and as a result a great deal of valuable data has been secured. In other cases a small amount of progress only has been possible, due

to the large amount of work on hand and for other reasons. Numerous publications have been issued from the section and will be found listed at the end of the colorimetry report.

The various investigations conducted during the year are described in greater detail in the following paragraphs:

Present Status of the Color-Standards Investigation.

The essential feature of the present status of the color-standards investigation may be described as follows:

Apparatus for the determination of spectral transmissive and reflective properties of materials by visual, photographic, photoelectric and thermoelectric methods is installed and in active use in various researches and tests. Such measurements constitute the essential physical basis of color specification. Care has been taken to design apparatus and formulate methods of observation and computation so as to convenience and expedite the conduct of this work; and every effort is made to keep these permanent installations always in condition to make measurements on short notice. The work of the past year has shown a very gratifying degree of agreement between determinations by different methods.

Notwithstanding the improvements that have been made, the methods just mentioned leave much to be desired from the point of view of rapidity of work; and a great deal of attention is now being given to the development of improvements to economize time of observation and eliminate tedious computations.

Considering the magnitude and complexity of the task, the progress on development and establishment of standard nomenclature is satisfactory and gratifying. From the very nature of the case, this is a subject which can not be brought to a definite conclusion for a number of years. It must go hand-in-hand with new experimental work and the crystallization of ideas on the subject among all interested in it.

The development and practical establishment of rotatory dispersion methods is in the active formative stage. Enough has been done to show the utility and value of the method but a vast amount of work remains to be done.

The practical and prompt handling of the technologic problems of color grading materials proposed to the Bureau by the industries is at present a most difficult matter because of the lack of fundamental data and standards. More effort should be directed to the solution of general fundamental problems even if it involve the apparent neglect of specific problems, because the solution of particular problems will follow easily when the fundamental knowledge is at hand.

Without attempting to outline the research which should be undertaken to extend over a term of years, it may be stated that the most pressing fundamental problems are:

1. The determination, definition, and establishment of recognized standards of average daylight and "normal gray light."

2. The quantitative correlation of color (sensation) and the spectral distribution of radiant power (stimulus). These should be regarded as the major problems of the coming year.

The impossibility of obtaining suitable optical instruments continues to be a most serious handicap to the general practice of colorimetry outside of the Bureau. It is useless to prescribe measurements without the instruments necessary to make them. The manufacture and supply of instruments now well standardized as well as the design of new ones is a most urgent need.

The education of the public interested in colorimetry from a practical point of view is an urgent need which is being partially met by occasional lectures, much correspondence, and by publications; but it is impossible to undertake this work as rapidly or extensively as is desirable.

Specific subjects which have made considerable progress during the year are reported upon in detail in the following paragraphs:

Standardization of Colorimetric Nomenclature.

One of the primary and urgent needs of colorimetry is an established and recognized nomenclature as well as systems of units, standards and symbols. The formulation and standardization of these matters has been carried on by the colorimetric section for the last two years, but it is necessary that general agreement be reached with all concerned. Action toward this end was taken by the Optical Society of America in January, 1919, a committee being formed with the chief of the Bureau's colorimetric section as chairman.

A comprehensive preliminary draft of a report on nomenclature and standards of colorimetry has been prepared and submitted to the Optical Society of America. This draft comprises about 50 typewritten pages and 6 tables.

The report presents for the critical consideration of other experts the system of nomenclature in course of development and in current use in colorimetric work at the Bureau of Standards. Particular detailed attention is given to names and symbols involved in spectral transmission and quantities related to it.

It is not considered advisable to print this report at the present time, but complete copies are being supplied to experts on this subject with requests for criticism and suggestions for revision. Two complete record copies have been deposited in the Bureau of Standards' library and may be consulted there or borrowed by mail.

Spectrophotometric Methods.

As has been repeatedly emphasized in previous reports, the physical basis of colorimetry is spectrophotometry. The visual, photoelectric, and photographic methods, mentioned in last year's report, page 128, have been used continually throughout the year, and have proved very satisfactory.

Certain changes and improvements in the visual and photographic apparatus are described very briefly in Bureau of Standards Technologic Paper No. 148 on the transmission of colored glasses. Still further improvements in these methods are contemplated. When they have been finished and thoroughly tested papers will be issued completely describing these methods.

A detailed description of the photoelectric method has been published as Bureau of Standards Scientific Paper No. 349. The null

method used has made it possible to eliminate many errors common to photoelectric deflection methods. The only variable in the process of making a determination of the transmission at any wave length is the accurately measurable distance of a small light source from the slit of the spectrometer. Measurements of spectral transmission can be made from 380 millimicrons in the extreme violet to at least 650 millimicrons in the red.

A modification of the method has also enabled measurements of diffuse spectral reflection, relative to a standard like magnesium carbonate, to be made over nearly the same range of wave lengths, but with somewhat less accuracy. Measurements of relative specular reflection have also been made. In addition, the method is applicable to the measurement of the relative radiant power of two sources and to the measurement of fluorescence, and could be extended into the ultra-violet if quartz parts were used instead of glass.

A thermopile and galvanometer have been installed with the photoelectric apparatus in such a way that spectral transmissions may now be measured either photoelectrically (null method, two photoelectric cells and electrometer) or thermoelectrically (deflection method, themopile, and galvanometer). The change from one method to the other can be made in a moment's time.

The large Hilger constant-deviation spectrometer glass prisms makes this thermoelectric method very suitable for the work of the colorimetry section. The method agrees well with the visual method from 600 to 700 millimicrons, and it not only extends the transmission measurements from 700 to 800 millimicrons, a region of considerable importance in certain colorimetric work and very difficult of accurate measurement, but it makes possible the transmission measurements to about 1,400 millimicrons, where 1 centimeter of water becomes practically opaque. Thus it is very suitable for the testing of dyes in solution. The special value over the range from 600 to 1,400 millimicrons is due to the fact that a much narrower slit, and therefore, a much purer spectrum, can be used than is obtained over this range with the usual infra-red spectrometer, which is intended primarily for the work at wave lengths longer than 1,000 millimicrons.

Measurements are being made of spectral transmission of high precision over the complete range from 220 to 1,400 millimicrons. The approximate range of the photographic method is from 220 to 500 millimicrons; the photoelectric, 380 to 650; the visual, 436 to 720; the thermoelectric, 600 to 1,400 millimicrons. This overlapping has enabled a more thorough comparison of methods to be made than has probably ever been done before, and has resulted in the detection and elimination of various errors which would otherwise have escaped notice. The excellent agreements between these different methods, as used during the past years, will be extensively illustrated in a forthcoming paper on the spectral transmissivity of dyes in solution.

The visual method is the only one at present available which measures spectral reflection in the proper way, i. e., the specimens are diffusely illuminated and the reflection measured at right angles to the surfaces. At present magnesium carbonate or oxide is taken for standard white as a comparison surface. The range and ac-

curacy for this method are precisely the same as in measuring spectral transmission. The photoelectric method as so far used is reliable only for perfectly diffusing surfaces. The agreement obtained between the visual and photoelectric methods for surfaces approximating to this condition is very good. Such agreements are extensively illustrated in a Bureau of Standards Technologic Paper (now in press) on the Munsell color system. A few measurements of reflection have been made with the photographic apparatus using the intense light from the quartz-mercury arc. These were only approximate, however, because of the discontinuous spectrum of this source. Nevertheless, the agreement with the photoelectric method was good. Plans are now being made for obtaining diffuse illumination from the underwater spark which gives the continuous ultra-violet spectrum used in transmission measurements and is in a manner analogous to that now used for visual work. The thermoelectric method method has not so far been adapted to reflection measurements over the range 600 to 1,400 millimicrons. This would be possible only with special apparatus of the highest sensibility.

The new illumination apparatus mentioned in last year's report has been thoroughly tested in respect to the conformity of transmission measurements with Lambert's experimental law for different thicknesses of liquids. These measurements were found to be in accord with the law for thicknesses from 1 to 100 millimeters. Improvements in the cooling and ventilation of this apparatus have been installed, and the thermostats mentioned in last year's report were placed in service about August, 1919.

A direct-reading instrument based on the principle of variation of thickness, mentioned as in course of design in the previous report, has been constructed in the Bureau's instrument shop and has satisfactorily passed its preliminary laboratory tests. It was exhibited and demonstrated at the convention of the American Oil Chemists' Society, New Orleans, May 11, 1920. The specification of the essential features of its design is being published in the chemists' section of the Cotton Oil Press (July or August, 1920). It is expected that a detailed illustrated description will be published by the Bureau during the coming year.

The Application of Rotatory Dispersion to Colorimetry, Photometry, and Pyrometry.

For about eight years studies in the application of rotatory-dispersion methods to colorimity and related subjects have been in progress at the Bureau. The method proves to be of fundamental practical importance. In order that it may be more generally understood and put to practical use a series of papers relating to it are being prepared for publication. A general paper outlining the subject and giving a résumé of past work was presented to the Optical Society of America, New York, February 27, 1920, and will be published in the journal of that society.

Extensive tables and graphs for computation to facilitate the application of this method are being prepared. Some of these are now in use at the Bureau, and it is hoped to publish them later for the use of others.

A New Study of the Leucoscope.

The leucoscope is an instrument developed and used by Helmholtz and his pupils between 1878 and 1888 primarily for the study of vision. Since that time practically nothing has been done with it. Recent experiments at the Bureau have shown the applicability of the instrument to pyrometry, and new laws of the instrument have been discovered relating its readings to temperature and spectral energy distribution in a light source or furnace. These data were communicated to the Optical Society of America, New York, February 27, 1920, and will be published in the journal of that society.

As the year closes the reduction of the data from these experiments promises to yield important information on the correlation of color (sensation) with the spectral distribution of energy (stimulus).

Investigation of the Spectral Transmissivity of Dyes.

The present pronounced interest in the development of the dyestuff industry has emphasized the need of accurate and reliable data on the properties of the dyes. Dyes are characterized by their remarkable selective absorption for light of different frequencies (color), i. e., light of certain colors is freely transmitted by the dye, while that of other colors is strongly absorbed. Also radiant energy in the infra-red and ultra-violet is affected in the same selective way. For purposes of identification and analysis of dyes reliable and accurate data on the transmissivity for a wide range of frequencies is of recognized importance, but little such data are available. During several years past the Bureau has been making extensive and elaborate preparation for a systematic investigation to obtain such data. This preliminary work is now finished and the investigation proper in cooperation with the Bureau of Chemistry of the Agricultural Department has been in progress for the past year. The Bureau of Chemistry is providing known analyzed samples and the Bureau of Standards is determining spectral transmissivities at various temperatures and concentrations throughout the visible and into the ultra-violet and infra-red. The dyes just at present in course of investigation are the "permitted food colors." Others will be taken up as rapidly as the work can be done. It is expected that the whole investigation will extend over a period of years more or less continuously, but partial reports will be issued from time to time as the data are obtained. These data will be in the form of tables and curves giving the specific transmissivities over a wide range of frequencies in a form convenient for the practical purposes of the dye analyst as well as for theoretical discussion of the nature of absorption and its relation to constitution. A paper is now in preparation which will describe in detail the methods and apparatus used and present the data on the seven food colors in tabular graphical form.

No provision has been made for continuing this investigation on a scale at all commensurate with its magnitude and importance. Until such provision is made, it will be necessary to suspend this work. The large amount of work which has been done was carried on at the expense of neglecting other investigations which, on account of their more fundamental and general nature, should be given precedence, and which must be actively resumed.

The Commercial Color Grading of Material in Which Color is an Important Property.

From a utilitarian point of view, the end and purpose of the color-standards investigation is the development of methods and apparatus to provide for the routine technical color grading of materials in which color is a point of interest; it is of the most vital importance in many industries. Those in active charge of the work know that this end can only be attained by founding the method on accurate, thorough knowledge of the very recondite and, to the layman, unfamiliar facts and phenomena involved. They are also, however, keenly aware of the need of applying this knowledge in a practical way to the practical problems presented. Time, thought, and effort are, therefore, divided between fundamental research and its application.

The materials which it is desired to grade by color in commerce are almost innumerable, including paints, dyes, inks, textiles, paper, flour, soap, tobacco, butter, and many other things. The Bureau's correspondence shows inquiries for information and advice on these problems from the most varied sources. In practically dealing with these problems general principles nearly always have to be specialized, and each problem requires individual treatment. Up to the present, the Bureau has been able to give very few of these problems adequate attention. Problems of this kind on which material progress has been made are noted in the following paragraphs.

Vegetable Oils.—The original investigation of the color of cotton-seed oil has been extended to other similar vegetable oils (peanut, soya bean, sesame, and coconut.) During the year a vast amount of experimental data on the spectral transmissivity and color of these oils has been obtained. Important relations between the spectral transmissivity and the color on the Lovibond scale have been discovered. The Bureau's recommendation that these oils be graded in terms of their transmissivity for definite wave lengths is still adhered to, but it has been found desirable to modify the recommendation in regard to the particular wave lengths selected for this purpose.

A report on this subject was presented to the American Oil Chemists' Society (formerly Society of Cotton Products Analysts) Convention, New Orleans, May 11, 1920. An abstract of this report is being published in the chemists' section of the Cotton Oil Press (July or August, 1920). A Bureau of Standards Technologic Paper is in course of preparation.

Paints, Pigments, and Inks.—A great deal of data on the spectral reflection of paints, pigments, and inks has been obtained. The spectral reflections of pigments submitted for test by DuPont de Nemours & Co. have been determined, and a report is being made to them. (See also reports on "Camouflage Paints" and "Three-Color Process Inks" below.)

Dyed Silks.—The spectral reflections of a number of dyed silks have been determined for Cheney Bros.

Sugar Solutions.—With the cooperation of the polarimetry section, the transmissivities of a large amount of sugar for particular wave lengths have been determined, and it appears that this method will be satisfactory for the routine grading of sugar solutions.

Investigation of Camouflage Paints.

The Bureau has determined the spectral reflections of paints used in camouflage pictures. A report has been prepared and it is expected to publish it later.

Standardization of Three-Color Process Inks and Filters.

At the request of the American Institute of Graphic Arts, the spectral reflection of 40 different samples of three-color process printing inks, red, yellow, and blue, each on coated and dull finished paper, has been measured and a report issued. In this report were included actual samples of all the inks as well as the spectral reflection curves. In the report were also given the spectral transmission curves of the red, green, and blue filters used in this kind of printing.

By invitation the chief of the Bureau's colorimetry section lectured on this subject before the American Institute of Graphic Arts, New York, February, 1920.

Investigation of the Lovibond Color Scale as Used in Grading Vegetable Oils.

A very thorough investigation of the Lovibond glasses used in color grading vegetable oils is in course and nearly completed. This work comprises: (*a*) The determination of the spectral transmission of the combinations of yellow and red glasses; (*b*) calibration of the glasses by rotatory dispersion colorimetry (Arons chromoscope); (*c*) calibration of the glasses by "leuoscope" readings; (*d*) reduction of the spectral transmission data to luminosity and its correlation with the Lovibond grade and the above calibrations.

The investigation confirms the previously observed irregularities in the Lovibond scale.

A partial report was made to the American Oil Chemists' Society, May 11, 1920, and a Bureau of Standards Technologic Paper on this subject is in course of preparation.

The Correlation of Color with Its Stimulus.

The general formulation of the conditions which must be satisfied by two different spectral distributions of energy (stimulus) in order that they may excite the same color (sensation) is a problem of fundamental importance in colorimetry. Some progress has been made in its solution. We find in all cases so far tested, including a wide variety of energy distributions: *If two different spectral distributions of energy excite the same color, the wave lengths of the centers of gravity of their luminosity curves are coincident.* Other conditions are in course of formulation as the year closes.

Investigation of Eye-Protective Glasses.

Work of this nature, during the past year, has been mainly routine testing performed at the request of various commercial concerns or of other Government departments. These tests have consisted either in the measurement of spectral transmission of miscellaneous glasses in the visible or ultra-violet, as was done in Bureau of Standards Technologic Paper No. 119 (abstract given in last year's report, p. 133), or in the measurement of various types of welding lenses to see if they meet the specifications for such lenses given in the Tenta-

tive National Safety Code for the Protection of the Head and Eyes of Industrial Workers, issued at the Bureau of Standards.

As shown by some of these tests, it is now possible to obtain welding lenses, suitable for the different types of work, which absorb or reflect all the harmful ultra-violet rays and all but a very small per cent of the infra-red or heat rays. The Bureau does not attempt to specify what is the proper amount of total light transmission for the various welding processes, as such information can be obtained only in actual trial by welding experts.

The Ultra-Violet and Visible Transmission of Colored Glasses.

The transmissions for the visible and ultra-violet of over 50 different kinds of colored glass, not classed especially as eye-protective, have been published (Bureau of Standards Technologic Paper No. 148). An abstract of this paper was given in last year's report, page 132. Various practical uses to which these glasses are put are indicated, such as ultra-violet signaling, railway signaling, improvement of visibility both for visual and photographic work, protection of the eyes, selective ray filters, and monochromatic light filters for use with the mercury, helium, and hydrogen lamps.

Colorimetric and Related Tests.

Formal test reports were made on spectral transmission of various glasses, inorganic salt solutions, vegetable oils, photosensitizing dyes, and colored gelatine filters; tests were also made on the color and spectral reflection of standard color cards, paints, and silks, on the relative radiant powers of various lamps, and on the transparency of 17 envelope windows. Thirty-one tests were reported from this section during the year. About 200 separate specimens or samples were included in these tests.

The applicants for these tests included the following: Navy Department (various bureaus), Post Office Department, Pennsylvania Railroad Co., Cheney Bros. (silk dyers), Philip Ruxton (Inc.) (ink makers), various dealers in eyeprotective glasses, and various oil refiners and chemists.

Information Furnished on Color, Colorimetry, and Related Subjects.

Information in response to requests has been furnished on color, colorimetry, colorimetric apparatus, and related subjects both by letter and by personal conference with visitors. About 140 letters of information were sent and about 50 such visitors were given oral information.

REFRACTOMETRY AND OPTICAL INSTRUMENTS.

In addition to the more or less routine tests of refractive indices of optical materials and on the performance of optical instruments, special attention has been given during the past year to a combined laboratory and field test of short base range finders; to an investigation of the cause of the formation of films on the optical parts of observing instruments and the remedy; to an investigation of the effect of variable contrast in the charts used for testing the resolving power of optical instruments; and to the standardization of design of the optical parts of laboratory telescopes.

Range-Finder Investigations.

In cooperation with the Ordnance Department, U. S. Army, the Bureau conducted a series of tests in its own laboratories and field tests at the Artillery School of Fire, Fort Sill, Okla., on 20 short-base, self-contained, optical range finders of various types. The main objects of this investigation were to determine (1) the true value of the range finder as a fire-control instrument, by testing its accuracy on different types of targets under different conditions of service: (2) an adequate acceptance test at the factory; (3) the relation between the accuracy of the instrument and its optical and mechanical design, with a view to improving the performance of instruments of this class.

The data obtained furnish knowledge as to the manner in which the probable error may be expected to vary with range when the infinity adjustment is correct and also when it is incorrect, for each instrument, and with the different types of targets. This gives the probable error due to accidental causes, including the limitation of the observer's eye. Up to the present there has been little information regarding this outside the statement of the manufacturer as to the least error to be expected under the most favorable conditions, and the assertion that under usual conditions the error may be assumed to be twice the most favorable value. The desirability of a scientific determination of the errors actually occurring in practice with targets of different types is obvious.

By properly interpreting the data the part of the actual error which is ascribable to a faulty infinity adjustment is determined. This is of special importance, as no other field tests appear to have been made in which these errors are separated from the others, although they arise from entirely different causes and must be separately remedied.

A preliminary survey of the data gathered indicates that under usual service conditions an incorrect infinity adjustment, introducing an error amounting to as much as 10 to 20 per cent of the range, may result from the use of adjustment laths which have not been properly fitted to that particular instrument. It has furthermore been concluded that the range finder is so easily thrown out of adjustment by shocks, unequal heating, etc., that the common practice in the Field Artillery, of allowing range finders to be trucked around and used in ranging for days without testing the adjustment, should be suppressed.

From the records of these tests interesting and valuable information will be gleaned on such questions as the improvement in the ability of the operator with practice, the effect of decreasing the brightness of the image in either one or both parts of the field, the accuracy of certain types of internal adjusters, the effect of temperature changes, the change in coincidence arising from the introduction of light filters, and the variations in the instrument from day to day.

"Filming" in Optical Instruments.

Many optical instruments are rendered unserviceable by the formation of deposits upon the reticles and other optical surfaces. At the request of the Ordnance Department of the Army an investigation

of the cause of these deposits and means of avoiding them was undertaken. The evaporation of the lubricant was found to be contributory to at least part of the filming, so a suitable lubricant was sought. The following information was gained from the tests: (1) Vaseline which has been boiled a long time is the best available lubricant for optical instruments: (2) Where more body is desired, a solution of pure rubber in vaseline may be used; (3) The presence of water is necessary in the formation of films, therefore absolute dryness is desirable. If this be impossible, good ventilation through dust filters of screens or cotton pads should be provided.

Triangulation Cameras.

A set of triangulation cameras for use in checking the fire of big guns on board battleships was redesigned and constructed in the Bureau's shops for the U. S. Navy. These were designed to expose the film, wind it, and set the shutter for the next exposure automatically on pressing a button.

Lens Tables.

Tables giving the dimensions of the lens blanks along with the constants and tolerances of the glass for various types and sizes of lenses are in process of formulation, of which the following have been completed:

For 26 sizes ordinary f/5 achromatic lenses, with data for their component elements.
For 31 ditto for telescope objectives.
For 25 sizes f/5 simple positive lenses.
For 25 sizes "spectacle" lenses.
For 21 sizes condenser lenses.

Test Chart for Photographic Lenses.

A method for testing a photographic lens by photographing a special chart has been developed, and a specially mounted camera constructed for this purpose. One of the advantages is the saving in wall space, a single line of charts 5 feet from the floor, together with a device for rotating the camera about its optical axis, serving to give a full test field.

Resolution Chart with Variable Contrast.

For testing the resolving power of telescopes a resolution chart with a series of illuminated lines against a dark background is commonly used. While this gives a fair comparison for different instruments, it does not necessarily indicate what the resolving power would be in actual use, because this is known to vary with the amount of contrast between the lines resolved and the surrounding field. A chart with variable contrast has been devised with the object of studying the variation in resolving power with contrast, with the special application in view of obtaining a more sensitive test than is available at present, for the effect of striae in optical glass.

Specifications for Sextants.

After extensive conferences with both makers and users of navigation instruments, specifications incorporating standard practice in design and performance of sextants have been prepared. Certificates issued for marine sextants will be based on these specifications.

Airplane Mapping Cameras.

Preliminary to the mapping of Santo Domingo and Haiti by the United States Geological Survey their camera was given a thorough optical investigation and its various mechanical devices tested.

For the Navy Air Service a dozen air-mapping cameras were given the customary optical tests, and fitted with attachments for locating the optical center of the photographs.

The Optical Constants and Chemical Composition of Optical Glass.

Collaboration with the optical glass section in determining the various optical constants of the glass produced by that section was continued during the past year.

In the production of new types of optical glass it is not sufficient to know the composition of the batch from which the glass is melted, but the chemical composition of the finished product must also be known. In cooperation with the chemistry division a preliminary investigation of the composition of several kinds of optical glass was undertaken. This work, which gave promise of success, has of necessity been postponed for the present.

Tests for the Purpose of Drawing Up Specifications.

At the request of the Army and Navy Bureaus of Ordnance complete measurements of the optical systems of various instruments were made for the purpose of writing specifications for them. Among these instruments may be mentioned panoramic sights, telescope sights for heavy artillery, tank sights, and officer of the deck spy-glasses.

Design of an Oscillograph Condenser System.

A condenser system, free from spherical aberration, for illuminating an oscillograph was computed for the electrical division.

Information Given.

Many requests from inventors were received for tests, calculations and suggestions in connection with various devices and schemes of an optical nature. Among those examined were a sextant for aerial observation, designed to measure the horizontal angle between objects at different elevations; a 6-inch base range finder; a stereoscopic gun sight; a machine-gun sight for night firing; an airplane position finder; a moving prism motion-picture camera: and a revolving mirror camera for photographing 1,000 pictures a second.

Information in letters, circulars, and drawings was sent out on request to Government agencies, manufacturers, and private individuals on such subjects as the silvering of mirrors, formulas for lenses and mirrors of special form, frosting of glass, index of refraction of various substances, the operation of motion-picture machines, the manufacture and testing of optical glass, the cementing of lenses, and the testing of photographic lenses.

Summary of Tests.

During the year 239 binoculars, 100 photographic lenses, 19 telescopes, 10 refractometers, and 54 samples of optical glass were given the customary tests, and tests of a miscellaneous nature ran the total up to 543.

RADIOMETRY.

In the general subject of radiometry some attention was given to the transmissive and reflective properties of materials. In response to inquiries an examination was made of the infra-red transmission of nitrocellulose submitted under the trade names of "celluloid," "pyralin," and "viscoloid," which substances were found to have the same transmissive properties.

The reflective properties of metal on glass mirrors was investigated. An examination was made also of the transmissive properties of new eye-protective glasses.

The general investigation of the effect of thermal radiation upon the electrical conductivity of materials was practically completed during the year, though several subsidiary questions remain for further inquiry.

Glasses for Protecting the Eyes from Injurious Radiations.

In view of the fact that apprehension was expressed that in the proposed safety code for eye protection, the specifications were so stringent that it might give one manufacturer a monopoly on the production of glass for protecting the eyes from injurious radiations, a series of experiments was made showing that colored glass easily obtained in commerce and used in the combination (1) red and green; (2) red and cobalt blue; or (3) brown and cobalt blue will meet the requirements for protection against ultra-violet and infra-red rays.

Constants of Radiation of a Uniformly Heated Inclosure.

The determination of the constants of radiation is beset with many difficulties owing to the fact that many of the subsidiary constants entering this determination are undergoing revision. Among these factors are the temperature scale, the refractive indices of the materials composing the prisms used, and new determinations of the effect of atmospheric absorption. As a result of these changes in the contributory data most of the old determinations of the radiation constants are subject to repeated revision.

During the past year therefore further consideration was given to the Bureau's determination of the constant of total radiation mentioned in the annual report of 1916. The conclusion arrived at is that the value of $\sigma=5.75\times10^{-12}$ watt-cm^{-2}. deg^{-4} previously published, remains unchanged. After making corrections for atmospheric absorption, etc., it is found that the average of all the reliable determinations by other observers is $\sigma=5.73$ to 5.74×10^{-12}.

Further attention was also given to this Bureau's determination of the constant of spectral radiation mentioned in the previous report. It was found that the temperature coefficient had not been applied to the refractive index of the fluorite prism for the yellow helium line, although it had been applied to the infra-red refractive indices. Making this correction reduces the previously published value ($c_2=14{,}369$) of the constant of spectral radiation by 0.3 to 0.4 per cent, giving an average value of $c_2=14{,}318$. Furthermore, after correcting the data of some of the other experimenters the average value of all observers is $c_2=14{,}320$ micron degrees.

Methods of Computing and Intercomparing Radiation Data.

Under this title a paper was published giving quick methods for computing spectral energy curves, using the Planck formula. In this a chart serves the purpose of intercomparison of thermal radiation constants with similar data obtained indirectly from ionization potential, photoelectric, and X-ray measurements. From an intercomparison of the data obtained by these methods, it appears that the value of Planck's constant h, computed from radiometric data, agrees very closely with that obtained by more direct measurement. From this intercomparison it further appears that to a close degree of approximation we have

$c_2=14{,}320$ micron deg., $\sigma=5.72\times10^{-5}$ erg. cm^{-2}. deg^{-4}., and $h=6.55\times10^{-27}$ erg.

Measurements of the Compotent Radiations from the Sun and from a Quartz Mercury Vapor Lamp.

This investigation involved the construction of a spectro-pyrheliometer consisting of a quartz lens and prism spectroradiometer on a simple equatorial mounting. An important part of the apparatus is a cylindrical quartz lens which enables the solar image to be focused on the spectrometer slit and the device to be operated by hand. The results obtained with this instrument show that there is no marked difference in the total amount of ultra violet radiation from these two sources. However, the spectral quality of the ultra violet radiation is very different, the ultra violet spectrum of the sun terminating at a wave length of 0.3μ ($\mu=0.001$ mm.), while that of the quartz lamp has 20 per cent of its ultra violet component radiation at wave lengths less than 0.3μ.

Reflective Properties of Metals and Alloys.

In collaboration with the Metallurgical Division of this Bureau alloys of aluminum with magnesium and with zinc were prepared and their reflecting power determined. Contrary to the reports of previous investigators, these alloys were found to tarnish and hence are unsuitable where permanency is of prime importance.

In response to inquiries for data thereon an examination was made of the reflective properties of monel metal; also of stellite and zinc. The latter is unique in having a deep minimum of reflectivity at 1μ, followed by an unusual high reflectivity beyond 2μ. The reflectivity curve of monel metal differs but little from that of pure nickel.

Photo-electrical Investigations.

An examination was made of the spectrophoto-electrical sensitivity of Case's thalofide cell, which is a laboratory preparation of thallium-oxy-sulfid. This substance has a wide, complex band of photo-electrical sensitivity extending from the visible spectrum to 1.2μ in the infra-red. There is a complex maximum at 1μ.

A comparison was made of the light sensitivity of the eye and of photo-electric cells, and the conclusion was drawn that there is nothing to indicate a similarity in the response of these two types of light-sensitive media.

From the results of various photoelectrical investigations, made principally at this Bureau, it is possible to formulate a few general

characteristics of spectrophotoelectrical sensitivity in solids. Among other things it appears that the photoelectrical response, to an equal energy spectrum, is fairly uniform throughout the visible spectrum terminating in a band or bands of high sensitivity in the near infra-red. Increasing the intensity of the radiation stimulus shifts the maximum of the photoelectric sensitivity curve toward the longer wave lengths. Decreasing the temperature of the substance greatly increases the intrinsic photoelectrical sensitivity throughout the whole spectrum and shifts the maximum of the sensitivity curve toward the shorter wave lengths.

A sample of molybdenite was found which has a region of photoelectrical sensitivity, the reaction of which is unique in being positive or negative depending upon the wave length of the radiation stimulus as well as upon the magnitude and direction of the current through the crystal. This discovery necessitated an investigation of the photoelectrical reaction as affected by the temperature, the intensity and wave length of the radiation stimulus, etc., and a correlation of these data with the meager data previously published on negative photoelectrical reactions in other substances.

Information Furnished on Radiometric Subjects, Conferences, Tests.

In reply to specific requests therefor, information was given on various radiometric questions such as for example the measurement of radiation in absolute value; transmissive and reflective properties of materials to be used for specific purposes, also methods of measurement of the same; source of ultra-violet light, methods of measurement and usefulness in sterilization; the radiation laws and their correctness; energy lost from fine wires; radiometers and methods of measurement of the emissivity of material such as molten glass; eye protective glasses, and substitutes for special glasses.

In addition to tests and replies to inquiries personal instruction was given to a party who was preparing to study the effect of radiation upon plant growth; also a representative of a manufacturing establishment was instructed in the minute details of construction of radiometric instruments.

Publications on Radiometry.

The following publications were issued during the past fiscal year: Scientific Papers, No. 338, Some Optical and Photoelectrical Properties of Molybdenite; No. 342, Reflecting Power of Stellite and Lacquered Silver; No. 344, Spectral Photoelectric Sensitivity of Silver Sulphide and Several Other Substances; No. 357, Constants of Radiation of a Uniformly Heated Inclosure; No. 360, Methods for Computing and Intercomparing Radiation Data; No. 362, Distribution of Energy in the Spectrum of an Acetylene Flame; No. 363, Preparation and Reflective Properties of Some Alloys of Aluminum with Magnesium and with Zinc; No. 378, A New Spectropyrheliometer and Measurements of the Component Radiations from the Sun and from a Quartz Mercury Vapor Lamp; No. 379, Reflecting Power of Monel Metal, Stellite, and Zinc; No. 380, Spectrophotoelectrical Sensitivity of Thalofide.

PHOTOGRAPHIC TECHNOLOGY.

Sensitometry.

A new instrument for measuring the filter factors of color sensitive materials has been designed and constructed. This instrument is constructed on the principle of a photometer, using a single source of light. Two beams of light, one from each side of the lamp, are reflected in such a manner that both of them are brought side by side to the plate to be tested. Just in front of the plate, and placed so that both beams pass through it, is the compensating filter which is used to reduce the spectral distribution of energy to that of average noon sunlight. These lamps and filter combinations when used under certain particular conditions have been adopted by this Bureau as a standard source of energy for sensitometry.

In the path of one of the beams is placed the filter to be tested with the plate. The lamp is moved from zero to various positions and an exposure given at each setting. When the lamp is moved one of the beams is lengthened and the other shortened by an equal amount. After these plates have been developed the difference in densities are measured by means of a polarization photometer. These density differences are plotted against the scale distances or settings of the lamp. Some of the densities will be larger on the side of the instrument without the filter (marked +) and the others will be larger on the side with the filter (marked —). Those having the density larger on the filter side are plotted above the scale and the others are plotted below the scale (scale=0). A line is drawn through the points, and where it intersects the scale is the place where the two beams are of equal photographic intensity for that particular plate and filter. From the scale distance, which is the amount by which one of the beams of light is lengthened and the other shortened, to obtain this match or photographic equality, and knowing the total path of both beams, is calculated the filter factor, using the inverse-square law.

During the past year the characteristics of 86 brands of American-made plates and films have been investigated. These light-sensitive materials were tested with the specially designed sensitometer mentioned in the last annual report. In most cases nine samples were cut from the plates and films and exposed in the sensitometer. These nine test pieces were exposed in groups of three, making a total of three complete tests on each brand of material. In each test the three exposed samples were developed for different lengths of time, so that the development velocity or the growth of contrast could be determined. In all cases the test specimens were developed in a thermostated developing bath. These tests gave the following characteristics in numerical values: Speed, contrast, and scale or range of light intensities that the material will record. These tests, including a number of special ones, required more than 8,000 density measurements.

The color-sensitive qualities were also determined by two methods: First, the plates and films were exposed in a specially designed spectrograph. This instrument gives in graphical form the relative sensitivity to the various colors of the spectrum. Second, the filter factors were obtained with the instrument mentioned above. Filter

factors are the numbers by which an exposure without a filter must be multiplied to obtain the same photographic effect when using that particular filter. Light filters used in photography are of all colors and of various intensities of color, and the filter factors not only vary considerably with the color filter used, but also with the brand of plate or film with which they are used.

In addition, a test of the resolving power of the plates and films is being conducted.

All of these data are being collected to form an atlas of negative emulsions, but at the present time it is available only to the Government departments.

Photostat Machine Paper.

Samples of several brands of photographic paper for use in the photostat machine were tested for the War Department. These tests showed the comparative speed, contrast, color sensitivity, and the filter factors. The developers for use with the above papers were tested for velocity of development.

Large Camera and Stand.

A 30 by 30 inch special process camera and stand, including copy holder, was designed for the Coast and Geodetic Survey. This equipment is now being constructed.

Camera for Bomb Trajectory.

Assistance was given the aircraft armament section of the War Department in solving a photographic problem in connection with airplane bomb trajectory.

INTERFEROMETRY.

In addition to the testing of several thousand precision end gauges, the principle of interference of light waves has been applied in measuring the thermal expansion of glasses with special reference to their annealing temperatures; the change in dimensions of dental materials on setting, under pressure, with temperature, etc.; the change in length of gauge materials with time and treatment, in order to obtain invariable gauges; and the change in diameter with temperature of "sealing in" wires.

Thermal Expansion of Glass.

This investigation was undertaken in connection with the Bureau's production of optical glass. A large number of optical glasses, plate glass, chemical glass, and commercial tubing were investigated. Length measurements were made in the temperature range between 20° and 650° C. All the glasses passed through a critical expansion region in which the expansion rate was two to seven times the normal value. This critical region, which for any one glass does not exceed 40°, was found for some kinds as low as 400° and with others as high as 575°. About 75° above the critical region the glass softens and contracts.

Physical Properties of Dental Materials.

This investigation was undertaken by the weights and measures and the optics divisions in collaboration, at a request from the

Surgeon General's Office of the War Department. The combined object of the investigation was to draw up specifications for filling materials and to develop methods for testing their different physical properties. Interference methods were used for measuring all dimensional changes.

Standardization of Precision Gauges.

End standards or precision gauges are blocks of metal, usually steel, having two opposite faces plane, parallel and a specified distance apart. These gauges are used to check micrometers and other measuring instruments, and also to serve as distance pieces for precise mechanical work. They are made so nearly perfect that interference methods are necessary in calibrating them. The method used requires standard gauges having the designated length of the one to be tested. Several sets of these standards were calibrated by direct comparison with the standard light waves. Using these the length of the gauge submitted for test is quickly determined with an accuracy of a few millionths of an inch. Over 20,000 of these gauges have been tested for manufacturers and users during the past year. A description of the methods will appear shortly in the American Machinist.

Seasoning of Gauge Material.

For the purpose of determining the permanency of gauge materials, during the past two years sample gauges have been selected from the products of different precision gauge manufacturers and these measured at given intervals of time. It is found that some gauges retain their original dimension remarkably well while others show changes varying from two to fifteen hundred thousandths of an inch. To find if possible the cause, and to eliminate these changes in steel, test specimens were made up and subjected to different heat treatments. A determination of the change in length of these specimens with temperature showed that hardened steel shows like glass a critical region in which its thermal expansivity differs from the normal value. The first hardening gave a critical region between 260° and 390° C.; rehardening introduced another critical region near 150° C. These variations in the expansion were removed and a permanent change in length produced by heating the sample above 390°.

Radial Expansion of Fine Wires.

Wires sealed in glass bulbs which are to be evacuated must have a thermal expansion very close to that of the glass, else the junction will leak around the wire if the expansion of the wire is too low, or the glass be cracked if the expansion is too high. The expansion of such wires was measured between 20° and 375° C, the wires varying from three-tenths to 1 millimeter in diameter and determined with an accuracy of 0.03 microns (1 micron=1/1000 mm.).

Information Given—Publications.

Several representatives of manufacturers of precision gauges were given instruction in the Bureau's methods testing precision end gauges. The following articles were prepared for publication: Physical Properties of Dental Materials in collaboration with the

thermal expansivity section of this Bureau; Bureau of Standards Technical Paper, No. 157; also in Dental Cosmos, March, 1920; Thermal Dilatation of Glass at High Temperatures, Journal Optical Society of America, May, 1920; and forthcoming Bureau of Standards Scientific Paper; Calibration and Dimensional Changes of Precision Gauges in forthcoming number of American Machinist.

SEARCHLIGHT INVESTIGATION.

The searchlight investigation section was organized as such in September, 1919, to take over the work in this line started by the colorimetry section. Much of the work reported here was started in that section and part of it entirely completed there. While the primary functions of the searchlight section are to carry out, in cooperation with the Engineers of the War Department, certain investigations in connection with searchlight illumination, and to perform necessary tests on search lamps and search lamp accessories, the investigation of the power possessed by different light for penetrating the atmosphere under different weather conditions, and the limiting conditions of vision under faint light illumination are of importance secondary only to that of the performance of the search lamps themselves.

Transmission of the Atmosphere.

A method has been developed and put into operation for obtaining the relative spectral transmission of the atmosphere under different weather conditions. Reports have been made to the War and Navy Departments and a preliminary report is in press.

The Diffusion of Light by the Atmosphere.

The loss of light in a beam penetrating large extents of atmosphere is principally from diffusion. This diffused light acts like a veil between the observed and the target. A report on this effect has been made to the War and Navy Departments, and an article is now being prepared for publication.

The Contrast Sensibility of the Eye.

The ease with which a target can be seen, when illuminated by a searchlight, depends upon the contrast in brightness and color between the target and the surrounding atmosphere. It is important to know the smallest target visible under given contrast illumination. Data obtained under simulated Army conditions were compiled and incorporated in (1) a report to the Engineer Corps of the Army and (2) Bureau of Standards Scientific Paper No. 366.

Tests of Searchlight Mirrors.

The most exacting demands of searchlight mirrors are perfection of form of the reflecting surface, high reflecting power, and durability of both under severe working conditions. The mirrors commonly used are parabolic glass reflectors silvered on the back surface. Less expensive and more permanent as to fracture are metal mirrors with front surface silvering. They are, however, less durable as to reflecting power, hence not so commonly used.

For a general test of the form of the reflecting surface an equipment for the so-called "line test" has been set up and satisfactorily operated. This test consists in photographing the image formed by the mirror of a white wall ruled with black cross lines.

For exploring the form of the mirror a method has been set up and satisfactorily operated of photographing after reflection the intersection of several narrow beams incident upon the mirror parallel to its axis. Certain modifications of this method are being made which are expected to facilitate the tests.

A special reflectometer has been designed for measuring the reflecting power of a mirror, and some attention given to the development of methods for detecting the existence of mechanical strains in the glass composing the mirror.

Lacquers and Enamels for Searchlight Mirrors.

The usefulness of metal mirrors depends on the production of a durable protective coating for the front surface silvering, which at the same time does not reduce its reflecting power to an undesirable extent. In cooperation with the ceramics division, some experiments have been made on the use of an inorganic enamel for the purpose. Investigation of this problem in cooperation also with the Army engineers will be continued.

Photometry of the High Intensity Arcs.

Because of flickering and color fluctuations ordinary photometric measurements on searchlight arcs are very tedious. On the other hand, because of their high power, direct-energy measurements of their radiant power are quite feasible. A physical photometer has been under development for this purpose.

Testing of Search Lamps and Accessories.

Two search lamps with distant electric control and position indicators, one of high power and the other medium, have been received for test from the Engineer Corps of the Army.

Tests for Lighthouse Service.

The comparative light transmission of plain and reinforced plate glass for use in the towers was determined for the Bureau of Lighthouses.

Information Given.

This included the uses of high-intensity arcs in peace time, general information on search lamps and searchlight illumination to manufacturers and representatives of foreign countries, and, through the National Research Council, to a foreign country, information on the absorption of light by the front-glass windows of search lamps.

Publications and Reports Issued During the Year.

Report on Military Search Lamps and Searchlight Illumination.

Report on the Efficiency of Search Lamps.

Report on the Distribution of Light Flux in Searchlight Beam and Some Considerations on an Ideal Searchlight Beam.

Report on the Relative Spectral Transmission of the Atmosphere; also issued as scientific paper (in press).

Report on the Contrast Sensibility of the Eye; also issued as Scientific Paper No. 366.

Report on the Diffusion of Light in a Searchlight Beam. (This will appear in a scientific paper in preparation.)

5. CHEMISTRY.

Chemical composition and purity of material; chemical properties and constants, including researches upon methods of analysis, specifications for technical materials, and preparation of pure materials for standardization work for the Government and for industrial and scientific laboratories.

PHYSICAL CHEMISTRY.

This section is concerned with the preparation and purification of materials required in physical measurements of precision—for example, refrigeration materials, calorimetric samples, materials for standard cells and for density determinations; determination of certain physical constants and development of methods for their exact determination.

Through a lamentable accident the chief of the section of physical chemistry, E. C. McKelvy, met his death in November, 1919. By reason of his loss and the subsequent resignations of several of those who served under him, the work of the section was very much delayed, and during the second half of the fiscal year was restricted essentially to completing as much as possible of the work in hand and getting the remainder in such shape that it could be looked after by the one remaining member of the section or held over until additional men become available.

Refrigeration Materials and Problems.

In continuation of past work involving the determination of important physical constants of refrigerants, the triple point of pure ammonia, or the temperature at which the solid, liquid, and vapor are in equilibrium, has been determined. As calculated by a member of the heat division, this temperature is −77.704° C. with an error not exceeding 0.01°.

Besides pure liquid ammonia, carbon dioxide and ethyl chloride were prepared and purified in considerable amounts, enough to meet the needs of the heat division for a year or two in determining the physical constants needed in refrigeration.

Purification of Materials for Special Purposes.

Naphthalene.—Enough naphthalene was prepared for use as a standard for calorimetry to last several years at the present rate of distribution.

After several years of inability to obtain benzoic acid that would yield a refined product sufficiently free from chlorine to be an irreproachable standard for calorimetry, a satisfactory article was finally found and is now being purified and issued.

Methyl Alcohol.—Last year's work on the preparation and purification of methyl alcohol was continued, and the new product will be tested for density by the division of weights and measures.

Atlas of Heterogeneous Equilibria.

The death of the chief of this section terminated all work on the Atlas of Heterogeneous Equilibria. The large amount of material

now on file is in such shape that it is readily available for reference work. It is very desirable that provision be made for the continuation and eventual completion of this work.

Critical Solution Temperature Work.

The study of the critical solution temperatures of carbon disulphide-ethyl alcohol and carbon disulphide-methyl alcohol, discussed at some length in last year's report, has been completed throughout the entire range of concentrations.

Glass-to-Metal Joint.

The work referred to a year ago on a glass-to-metal joint was completed. The best joint developed consists of glass platinized and joined to tinned metal tubes. Such a joint will stand a pressure of 6,000 pounds per square inch.

Glass-to-Glass Joint.

It is often necessary to join together glasses of different kinds. Direct joining is impossible if the glasses have very different coefficients of expansion. The difficulty is usually overcome by interposing a glass or glasses of intermediate character. It has been possible thus to join two glasses of widely differing character—pyrex and soft glass—by means of a series of eight glass mixtures consisting of various proportions of pyrex and soft glass. Such joints have proven to be satisfactory in service, but unfortunately attempts to make the intermediate glasses on a somewhat larger scale proved abortive because of the high temperature necessary to obtain uniform mixtures.

Tubing of Good Quality for Glass-Blowing Purposes.

On account of the poor quality of soft glass tubing suitable for glass-blowing use that is available on the American market, an attempt was made to improve the situation. A sample batch of glass made by the glass section at the Bureau was tested in that laboratory and also sent for test to over 20 different authorities throughout the country. So favorable were the comments received that an effort is being made to interest certain manufacturers of glass in its production or in some modification that shall be equal to the best German product of prewar days.

Minor Problems.

During the year many minor problems were presented to the section, among them the following:

(1) Preparation of universal wax for the use of the Bureau.
(2) Testing of explosibility of ammonia-air mixtures.
(3) Testing of ozonator for the production of ozone.

ELECTROCHEMISTRY.

Included in this work are studies of electrodeposition used in electrotyping and electroplating, the latter being made up of investigations of zinc, lead, nickel, copper, silver plating, etc.

Electroplating Investigations.

During the first part of the fiscal year the work upon the effect of pickling on the physical properties of steels was completed and the results were published. It was impossible, however, to complete the work which was planned upon the effect of plating operations on the physical properties of steel. As opportunity offers it is hoped to continue this investigation.

Some time was also devoted to the study of zinc-plating solutions, but it was impossible to carry these experiments to completion. There is a great need for study of this subject, and such work should be carried on as soon as possible.

Most of the time of this section during the year has been devoted to cooperation with the Bureau of Engraving and Printing in connection with the installation of a new plant for the electrolytic production of printing plates. The preliminary studies were carried out at the Bureau of Standards, and the plant was designed and installed under its supervision. The Bureau has also cooperated in working out the manufacturing details of the process. This plant is now in operation and is producing plates which have yielded very satisfactory service. It is hoped that by addtional research and control work further improvements may be made which will permit greater production and service.

Since this work for the Bureau of Engraving and Printing required practically all the services of the section, it was not possible to carry on any extended or fundamental investigations of plating. The knowledge and experience gained, however, in connection with the operation of copper and nickel solutions will, it is believed, be of value both to electrotypers and electroplaters. So far as possible, the information gained in this connection will be made public for the benefit of the above industries.

Illustrated lectures upon the structure of electrodeposited metals were given to branches of the American Electroplaters' Society located in a number of the principal cities. Through such lectures and through the resulting discussions and correspondence, it is believed that the work carried on in this field can be made immediately useful to the electroplaters, chemists, and manufacturers, and the value and possibilities of such research work can be emphasized. The American Electroplaters' Society, which is an educational and scientific organization, has been of great assistance in promoting an interest in an application of the results of scientific work in the field of electroplating.

As a result of increased interest on the part of both electroplaters and manufacturers, the field and need for reliable information upon electroplating is increasing. Since the electroplating industry is usually carried out incidentally to other manufacturing operations, its importance and magnitude are frequently overlooked. When it is realized, however, that it finds application in the manufacture of practically all articles made of metal and that it determines largely the attractiveness and service of the finished articles, its importance to the public can be readily appreciated. In the silverware industry alone the value added by electroplating is sufficient to justify the expenditure of considerable amounts for research work to improve the quality of the products. The electrotyping industry is

fundamental to the whole printing industry and presents a field in which there is as much possibility of improvement through research as in electroplating. Many problems, such as nickel deposition, can be studied to advantage with a view toward their application to both electroplating and electrotyping.

METALLURGICAL CHEMISTRY.

The preparation of metals and alloys required in connection with meallurgical investigations and special methods of analysis for such products are handled by this section.

The work done by the chemistry division in connection with metallurgy, however, is reported under "Metallurgy" (p. 244).

GAS CHEMISTRY.

Methods of preparation, purification, analysis, and testing of gases, including fuel and illuminating gas, and special gases, such as hydrogen, oxygen, nitrogen, and argon, form the work of this section.

The Thermal Conductivity Method for Gas Analysis.

Probably not far from half of the time and energy of the section has been devoted to the development of recording gas analysis apparatus depending upon thermal conductivity, and to the construction of such apparatus for use in various Government establishments. The features of this apparatus which give promise of the most extended usefulness in industry were invented and have been developed to the point of successful commercial use within this section. The first plant installation was a single-point recorder placed, just a little more than a year ago, in the experimental helium plant of the Bureau of Mines, at Petrolia, Tex. This apparatus was an immediate success and led to the demand for, and the construction of, another single-point recorder, two 6-point recorders, and one 16-point recorder for use in connection with the various helium projects, one 4-point recorder for use in analyzing water gas at Langley Field, and one hydrogen purity recorder for use at the same field. All of this apparatus has been constructed and all but the 16-point apparatus has been installed. The two 6-point recorders, which determine helium, methane, ethane, and nitrogen in various mixtures are reported to be giving particularly good satisfaction. The Bureau has been requested to construct a 4-point recorder for determining sulphur dioxide in the naval powder factory at Indianhead, Md., and another 6-point recorder for the Bureau of mines. Apparatus was also constructed for the Fixed Nitrogen Research Laboratory at American University for the determination of ammonia, and the Bureau was recently informed that when the large nitrate plant at Mussel Shoals is reopened it will be asked to supply the recording equipment for that plant. Apparatus of this character is under construction elsewhere for at least five manufacturing concerns; and one university laboratory is known to have employed the method in experimental work. The time required in constructing and empirically calibrating this apparatus has prevented the important study of fundamentals upon which further progress in its development must be based.

Balloon Fabrics.

The testing of balloon fabrics has continued along the lines established in previous years. A total of 1,449 individual tests were made upon 349 samples. Most of this work has been done in connection with the efforts of the Army and Navy to develop a much less permeable fabric of light weight and continuous gas film. During the year the Bureau has developed and used methods for testing the strength and slippage of balloon seams at elevated temperatures. Some fundamental work has also been done upon the permeability of rubber to nitrogen and to water vapor. An exhaustive paper upon "The Permeability of Rubber to Gases" has been prepared for publication.

Study of Laboratory Gas Analysis Methods.

The section has recently been able to begin the extensive program of investigation of gas analysis methods outlined several years ago. A considerable amount of work has been done upon the development of improved apparatus, and a theoretical and experimental study of the absorption of gases by liquid reagents has commenced. The preliminary results obtained in this study are of great interest, but nothing is yet ready for publication.

Hydrogen Alarm for Use in Submarines.

The section has developed several different instruments for the purpose of detecting the presence of hydrogen in submarines, and has tested 10 or 12 instruments devised by others for the same purpose. On account of the extremely severe conditions to be met in submarine service, none of these has proven satisfactory. Last summer a new instrument was devised for the definite purpose of trying to meet all the conditions which were responsible for the failure of the earlier instruments, although to do this it was necessary to sacrifice many of their advantages. The new instrument has been tried out at the New York Navy Yard with favorable results and has been tentatively adopted for use by the Navy Department.

Bibliography of Gas Literature.

An extensive bibliography of the scientific literature relating to the physical and chemical properties of gases, and including many related subjects, is being prepared. About 11,000 references are now included, and all have been very carefully arranged and indexed. This bibliography is already proving of the greatest value, although probably less than half completed.

Water Indicator.

Some time has been devoted to an effort to develop a satisfactory indicator and alarm for the presence of minute traces of water vapor in a gas. Such a device was urgently needed for use in connection with the synthetic ammonia process employing sodium amide as a catalyst. The apparatus developed, which depended upon the electrical conductivity of a film of some very hygroscopic substance, such as phosphorus pentoxide, was only moderately successful, and work upon it was abandoned when it became apparent that the Fixed Nitrogen Research Laboratory was no longer interested in the matter since it had found a superior catalyst unaffected by water.

Consulting Work on the Properties and Production of Gases.

The section is constantly receiving inquiries from many sources, but particularly from other Government departments, for information of all sorts relating to the production, handling, properties, and analysis of gases. Such inquiries require a great deal of time in the aggregate, and frequently lead to rather extensive investigations. One such investigation involving some weeks of laboratory work was made to determine the practicability of a proposed process of making acetone from carbon dioxide and methane. Another was concerned with the desirability of trying to reduce the danger of balloon fires and to save hydrogen by burning the oxygen out of the balloon by means of electrically heated wires. At the present time the section is working upon the important problem of improving the "Messerschmidt" process used by the Air Service at Langley Field and by the Navy at Pensacola and Hampton Roads for the generation of hydrogen.

New Automatic Method for Gas Analysis.

Preliminary work has been done upon an automatic method of gas analysis depending upon the velocity of sound in the gas. This method is believed to offer exceptional opportunities for the development of a very cheap and quick-acting apparatus for plant-control work, especially for boiler firing.

Work for Other Divisions of the Bureau.

This section is frequently called upon to assist other divisions and sections, usually by making gas analyses in connection with their problems. An unusually heavy demand of this kind has recently been made in connection with the oxy-acetylene welding tests conducted by division 7. A rather elaborate interferometer set-up was made for this purpose, and nearly 550 samples of oxygen were analyzed.

REAGENTS AND APPARATUS.

In this work may be mentioned the study of methods of testing reagents and apparatus to be used in chemical analysis, including study of chemical glassware, poreclain, platinum, and platinum substitutes.

Chemical Reagents.

Owing to reductions in the staff and lack of funds the systematic study of the so-called "analyzed reagents" has been held in abeyance. A limited amount of work has been done on the testing of reagents purchased for the use of the laboratories of this Bureau. The results obtained indicate that there is room for improvement in many of the reagents on the market. As the study of chemical reagents involves standards of quality and standardization of methods of test it is of direct interest to all scientific and industrial laboratories and indirectly affects all users of the products of the industries. For this reason means should be provided for prosecuting this work in a systematic way.

This study will be undertaken in cooperation with the American Chemical Society and with the manufacturers of reagents. One of

the sectional staff is a member of the American Chemical Society committee on "Guaranteed Reagents and Standard Apparatus," and has attended several meetings of this committee. The report of this committee for the past year is published in the Journal of Industrial and Engineering Chemistry, volume 12, page 439 (May, 1920).

Chemical Apparatus.

The second annual meeting of the Association of Scientific Apparatus Makers of the United States, held at Washington, D. C., on April 22 and 23, 1920, was addressed by the Director of this Bureau, and on invitation of the Director the members inspected the various departments of the Bureau. This association is working in conjunction with the National Research Council, American Chemical Society, Bureau of Standards, and various other scientific bureaus of the National Government with a view to standardizing and thus cheapening the commoner and most used forms of apparatus.

Platinum Research.

The research upon the chemical and physical properties of the platinum metals has been continued. This has consisted mainly in the refining and preparation of the pure metals from the various lots of the impure metals loaned to the Bureau by the United States Assay Office, and by the Nitrate Division of the Ordnance Department, United States Army. About 600 grams of pure platinum, 100 grams of pure palladium, and 75 grams of pure iridium have been prepared. In this work a comparative study was made of certain methods of purification of platinum and iridium. The knowledge gained in the purification of these preliminary quantities will greatly expedite the work of purifying the material on hand. Some experimental work was done on the analysis of gold-palladium and gold-platinum alloys. A series of platinum-iridium alloys, ranging from 0.01 to 1 per cent iridium, were prepared for the spectroscopic section. Owing to the press of other work and the reduced personnel, practically no progress has been made in the study of the physical properties of the pure metals and their alloys. However, a program for this investigation has been formulated in cooperation with other divisions of the Bureau. A representative of the Bureau visited and conferred with the various platinum refiners and the technical staff of the United States Assay Office. Analyses were made of various samples of platinum and platinum-iridium wire for the War and Navy Departments. Special check or referee analyses of nine samples of platinum sludge, representing 9,000 pounds of this material from a contact sulphuric acid plant, were made for the Bureau of Supplies and Accounts, Navy Department. This work involved a study of analytical methods and the results were of value to the Navy Department in fixing the selling price of this material.

A special fund having been appropriated by Congress for "the purchase of platinum and other rare metals," the following have been purchased to be used in the platinum metals research:

Five troy ounces of osmium, 90 per cent pure.
About 16 troy ounces of rhodium, about 95 per cent pure.
About 7 troy ounces of ruthenium, about 95 per cent pure.
Thirty-five troy ounces of Colombian platinum ore.
About 22.5 troy ounces of pure platinum.
Fifty troy ounces of pure gold.
About 20 troy ounces of silver.

Platinum Theft.

Between 4.30 p. m., March 17 and 9 a. m., March 18, 1920, about 70 ounces of platinum laboratory ware (mainly crucibles, covers, and dishes), valued at about $10,900, were stolen from the Chemistry Building. This ware was stolen from locked drawers. No platinum in use, or not locked up, was disturbed. No clue has been obtained in this case, although the matter was reported on March 18 to the police authorities. However, on April 2 two men were arrested in New York City trying to sell about 284 ounces of platinum sponge. This platinum was claimed by a New Jersey firm that had been robbed late in December, 1919. As the platinum stolen from this Bureau might have been in this lot, the Bureau of Investigation of the Department of Justice, at the request of the Bureau of Standards had their agents look into the matter. A member of the Bureau's staff was sent to New York to assist in this investigation. The prisoners claimed that the platinum was obtained by placer mining in Ontario, but this statement was proven false. A sample of the material was brought to this Bureau and a careful analysis made, showing platinum of higher purity than the usual metal of commerce and of totally different composition from that lost by the New Jersey firm. The Bureau of Chemistry, U. S. Department of Agriculture, assisted this Bureau by making a microscopic examination of the physical structure of the sponge. The results of the analysis indicated that the sponge was probably obtained from platinum chloride solution of a purity attained by the U. S. Assay Office in the refining of platinum for use in war-time powder plants. The chloride solution is used to impregnate the "contact mass" used in the manufacture of sulphuric acid. Deductions drawn from certain apparently irrelevant statements made by one of the prisoners, and suggestions by a member of the staff of the U. S. Assay Office, led to the conclusion that the material was stolen from a Government munitions plant, either at Nitro, W. Va., or at Jacksonville, Tenn. Although the officials of the Ordnance Department reported that their platinum stocks had been checked up and found intact, the investigation was continued. A visit was made to Wilmington, Del., to inspect certain photographs of former employees, and then to Nitro, W. Va., without any results. Finally, the Old Hickory Powder Plant, near Nashville, Tenn., was visited, and an inspection of the employment records of former employees led to the identification of one of the men under arrest in New York. Further inspection at this plant showed that at least 2,250 ounces of platinum sponge, prepared from platinum chloride solution by their chief chemist, were missing. As the result of these disclosures, the man in custody in New York confessed to complicity in the theft of the platinum from the Old Hickory plant, involving the chief chemist as the principal in the matter. The latter was placed under arrest and at present writing the two men are awaiting trial.

Miscellaneous Tests.

Comparative tests of laboratory glassware were made for the Medical and Hospital Supplies Division of the War Department. Tests of ampules were also made and assistance rendered in the preparation of specifications for ampules, medicine bottles, test tubes, and various chemicals. In cooperation with the manufacturers, tests

were made of American-made filter paper. The results indicated that this paper is superior to most of the papers on the market and practically equal to the best foreign-made paper.

ANALYTICAL METHODS AND STANDARD SAMPLES.

These investigations cover general methods of chemical analysis, with special reference to methods of standardization; preparation and analysis of standard samples of iron, steel alloys, ores, chemicals, etc.

Standard Analyzed Samples.

The number of samples called for during the fiscal year 1919–20 was 5,676, as against 4,944 in the year 1918–19, a gain of 732. The distribution was as follows: Irons and steels, 3,973; brass, 104; ores, 346; sodium oxalate, 409; naphthalene, 163; benzoic acid, 298; sucrose, 138; dextrose, 33; metals for melting points, 135; cement for testing sieves, 77.

The popularity of the samples is again attested by the largely increased demand and is the strongest possible argument for a restoration of the special fund which was stricken out of the appropriation bill for the year 1920–21. In order that the needs of the industries and of educational establishments may be adequately met, the special fund formerly provided for this purpose should be restored, and increased to $15,000. With this amount annually assured it would be possible to place the whole work upon a self-supporting basis. Certainly only a lack of understanding of the situation could have led Congress to fail to provide this appropriation of $5,000 for work which brought to the Federal Treasury more money in fees than the sum appropriated. The fee value of the samples issued in the past fiscal year was over $11,000.

Two new samples were added to the list during the year—No. 49, melting-point lead, and No. 50, chrome-tungsten-vanadium steel, and two others (No. 51, a high-carbon steel, and No. 52, a cast bronze) will soon be added. Seven samples were renewed and six other renewals are in various stages of mechanical treatment.

Analytical Methods.

Apart from the preparation and distribution of standard samples, the work of the section has consisted in research on analytical methods and in analytical work on materials which did not properly fall to any of the routine laboratories.

LUBRICATING OILS, RUBBER, PAPER, TEXTILES, INK, AND GLUE.

This section is concerned with chemical analysis and investigations of oils, rubber, paper, textiles, ink, glue, airplane dopes, etc., with special reference to meeting particular requirements.

Airplane Dopes.

Before the end of the preceding fiscal year there was a marked falling off in the work on these materials. At present only an occasional sample is received for test. The subject has been so well worked out and dopes of such excellent quality are now being made

that it is necessary only to test delivery samples. Unless some new basic material supplants cellulose acetate, it is not likely that there will be any great improvement over what is now used.

Rubber.

Full details of the Bureau's work on rubber, including that of the chemistry division, are given in the report on rubber (p. 210).

Textiles.

Various dyed fabrics were tested for fastness of color. Samples of woolen and silk goods were analyzed to determine their composition.

A considerable part of the work was the determination of the oil content of numerous samples of rope and the examination of flax packings.

At the request of the National Safety Council, tests were made of ropes which had been specially treated to make them resistant to the action of acids. Various bituminous and other mixtures were prepared and used. A more complete account of this work will be found under division 7, page 180.

In cooperation with the War Department the bleaching and dyeing of stained cotton was studied. This cotton became discolored while still in the boll, and varied from yellow to bluish. It was found that it could be bleached without serious difficulty and could then be dyed any desired color. The bleaching was not necessary when the cotton was to be dyed in shades of brown or olive drab.

Pearl Buttons.

A great deal of time was spent in attempts to bleach buttons made from the shells of the fresh-water clams of the Mississippi and its tributaries. The white buttons are the most valuable, but they can be made from only a small percentage of the shells. Most of the shells are colored pink, yellow, brown, or gray shades that may be almost black. Some of these colors are due to organic compounds produced by the clam, while others are the result of the deposition of fine silt upon the shell when the water is muddy. The iron compounds in the silt can not be removed without dissolving also the calcium carbonate of the shell. The organic colors can be bleached by treatment with hydrogen peroxide, at least to some extent. Ultraviolet light also removes these colors, but this process is slow and expensive.

Fireproofing Fabrics.

The aerial mail service of the Post Office Department was very anxious to have the mail bags fireproofed so that in the event of an accident the mail would be in a measure protected. Tests were made of a number of samples submitted, and fabrics were treated by different processes before the problem was solved to the satisfaction of the service.

Filter Paper.

Because of the fact that it is desired to produce filter paper in this country which will prove as satisfactory as that formerly made abroad numerous samples of paper pulp and paper were investigated

in cooperation with the paper section. These samples were treated with acid in order to learn how much of the mineral matter could be removed in the manufacture of "ashless" filter paper. Various papers were tested for speed of filtration and for retention of fine precipitates.

Clay for Paper Filler.

A considerable number of clays, mostly from American sources, were analyzed for the paper section to determine their suitability for paper making.

Printing Inks.

There was practically no routine testing and analysis of these materials, but considerable time was spent in developing a method for the quantitative measurement of certain of their physical properties upon which their behavior in the press depend. The method can be applied as well to other materials of the same nature, as paint pigments in oil, tars, etc.

Writing and Copying Inks.

A great many writing and copying inks were tested to assist the General Supply Committee and the Post Office Department in awarding contracts, and also to check deliveries made on purchases.

The use of ink powders and tablets and of concentrated ink seems to be on the increase. As stated in last year's report, these can not be recommended for use in connection with permanent records if only dyes are employed in their manufacture. However, several brands of powders and tablets now on the market contain the ingredients of iron gallotannate ink of good quality. Properly made concentrated ink should also be entirely satisfactory if it is not too strongly diluted. These remarks apply only to black inks. Red and other colored inks are always made from dyes, and there can be no objection to their being put on the market in dry form.

Stamping, Marking, and Related Inks.

Among the other kinds of ink tested were stamping, duplicating, stenciling, and similar inks. These were given tests designed to show whether or not they were suitable for the purposes for which they were intended.

Typewriter Ribbons.

Many ribbons for use on typewriters, adding machines, etc., were tested. The quality of the fabric, the amount of ink, and the permanence of the writing were all given consideration.

Carbon Papers.

The nature and amount of the coating were determined. The number of copies obtainable and their freedom from smudging are important considerations.

Glue, Mucilage, Paste.

Numerous samples were tested during the year for different branches of the Government.

An interesting piece of work was the preparation of glue from salted fur-seal flippers, at the request of the Bureau of Fisheries. The dried and salted flippers were first cut up and soaked, after which they were boiled to obtain the glue. A comparatively large yield of good glue was obtained. It had the disadvantage of a rather strong fishy odor.

Miscellaneous Materials.

Among the miscellaneous materials tested or analyzed were the following: Chestnut bark extract for making black writing ink, leather softeners, vulcanized fiber, celluloid, laboratory porcelain and grinding waste from the manufacture of saws.

METALS, CEMENT, BITUMINOUS MATERIALS, ETC.

The field covered by this section includes the chemical analysis of metals, among which may be mentioned iron, steel, nonferrous metals, alloys, such as brass, type metal, and solder; coated metals, such as tin plate and galvanized metals; lime, plaster, cement, concrete, and bituminous materials, including tars, asphalt roofing papers, roofing felt, etc.

Chemical Work on Metals and Alloys.

Because of depleted personnel very little except routine testing could be done in connection with metals and alloys. Mention is made in the following paragraphs of a few of the special problems presented for investigation.

Analyses were made of a number of German motor parts of various makes, which showed that chrome and chrome-nickel steels were used to a considerable extent. In the absence of these alloying elements high carbon and high manganese steels were used.

A sample of nichrome wire was received for examination from the Inventions Section, General Staff, United States Army, which had been in constant use at red heat for four years. The iron content was very low, and the general composition was similar to the alloy chromel. Such wire may prove to be suitable for a variety of uses.

An interesting alloy, "aterite," having a very high coefficient of expansion, resistant to corrosion, and not softening below 1,000° C. was found to have the following composition: Copper, 52.4 per cent; zinc, 9 per cent; nickel, 30.7 per cent; lead, 1.9 per cent; tin, 0.8 per cent; iron, 4.5 per cent; manganese, 0.3 per cent; carbon, 0.14 per cent.

At the request of the Navy Department, the effect was studied of approximate marine conditions upon "stainless" steel for use in periscope tubing. The cooperative study included preparation, heat treatment, microscopic examination and salt spray tests of 14 samples of steel. The results indicate that this type of steel is of advantage for the use proposed.

Tests to determine the effect of water saturated atmosphere upon electrical contact springs having various depths of gold plating over steel finish, electroplated zinc, and sherardized zinc, were made. The tests indicated that the gold-plated sherardized coatings were mark-

edly superior in their resistance to corrosion by the moisture-laden atmosphere.

In preparation for tests to be made in cooperation with the American Society for Testing Materials to determine the effect of immersion in running water upon sheet metal, 882 samples of 16 and 22 gauge metal were prepared, of which 294 will be tested at the Bureau.

Antifreezing Solutions.

During the year numerous requests have been received for copies of our preliminary report on antifreezing solutions for automobile radiators. Press of other work has prevented extension of the work to a degree that would justify a subsequent report. Of the materials submitted for use as antifreezing agents there is none which warrants the recommendation of solutions other than of alcohol and water.

Boiler Waters.

Numerous inquiries for information concerning the problems involved in handling steam boilers indicate widespread interest and the need for more investigational work.

Bituminous Materials.

Prepared Roofing.—The war-time specification for prepared roofing has been revised. The statement that the roofing obtained under that specification was inferior was investigated by inspection of many buildings in several of the Atlantic States and analysis of the material used. Failure was, in most cases, due to improper or careless methods of laying or because the samples were originally not truly representative. Also, as the specification was prepared under war-time conditions, concessions had to made of which some are not now necessary, so the revised specification has been designed to insure a product of higher grade. Only a very limited amount of prepared roofing is now used by the Army, but the specification is used by the Panama Canal and is available for general use.

An investigation was also undertaken to determine if tensile or bursting strength of the roofing as received and after exposure was a measure of quality. The results were negative, for while the strength was increased by exposure because of hardening of the felt, as was to be expected, no relation was observed that could be interpreted as a measure of quality.

Built-up Roofing.—Few specifications other than those of manufacturers have been available for built-up roofing, in spite of its importance in the more permanent class of construction, where it is being used to an increasing extent by the Office of the Supervising Architect of the Treasury and by the Navy Department. These offices have asked the Bureau for assistance in formulating more definite specifications.

Coatings for Concrete Ships.—The original specification for a bituminous coating for concrete ships called for a fairly hard coating, so as to prevent flow from water pressure. The importance of this point was apparently overestimated, and it is now felt that a softer coating to bridge cracks is desired. The specification has been modified accordingly. The information is applicable to other needs than concrete ships and is being so utilized.

Chemical Analysis of Cement and Lime.

The routine and chemical testing of cement declined markedly during the year. Full details of the Bureau's work on cement are given in the report on cement, page 188.

In cooperation with the interdepartmental lime committee and at the request of the lime section of the Bureau an investigation was made of the various methods for "available lime" in such materials as quicklime and hydrated lime with variable magnesia content. Of the seven short-cut methods tried only the Scaife method seemed to have any apparent value. Further work is now being carried out to see if this method can be modified to give better results.

Miscellaneous Tests.

About 90 samples of alkali soils and waters were analyzed to obtain data for various investigations of the cement section, which is conducting a study of the effect of alkali waters on cement drain tile.

In response to many inquiries for a method of rendering concrete resistant to acids a bituminous coating has been tentatively recommended for the purpose.

In analyzing asphalt varnishes a method was needed for determining the fatty oils. Such a method has been developed which depends on solubility of the fatty acids in ether and later ethyl alcohol, in which the bitumens are insoluble.

PAINT, VARNISH, AND SOAP.

This section is concerned with the chemical analysis, testing, and exposure tests of paint and varnish, as well as the chemical analysis of and specifications for soap.

Cooperation with Paint Manufacturers' Association.

Arrangements have been made with the educational bureau, Paint Manufacturers' Association of the United States, and National Varnish Manufacturers' Association for cooperative work on problems of interest to the paint and varnish industries. This association was given the use of the Bureau's facilities from November 18, 1919, to May 15, 1920, during which time the specific gravities and "bulking figures" of most of the pigments on the American market at this time were determined. The results, which will be published by the Paint Manufacturers' Association with proper credit to the Bureau, should prove of considerable value to the paint industry, since the data are necessary for accurate calculations of yield and hence cost per gallon of manufactured paints.

Interdepartmental Committee on Paint Specification Standardization.

This committee has been very active and has made good progress. While the greater part of the labor and responsibility of preparing the specifications issued has been borne by this Bureau, the other members of the committee have rendered invaluable service. The specifications so far issued will probably cover more than half the materials necessary for general protective painting; and while the work of the committee will never end, it is believed that the most difficult of the really important phases of its work have been covered.

CHEMICAL TESTING AND PUBLICATIONS.

Chemical Testing.

The number of chemical tests made in the chemical laboratories during the fiscal year was 9,317. This number is hardly more than half that of the preceding year, but the decrease is natural, being a direct result of the lessened activities of the military branches of the Government since the close of the war. Distributed by types of materials, the tests were as follows: Ferrous metals (irons and steels), 757; nonferrous metals, alloys and coated metals, 867; cement and cement materials, 1,746; bituminous products (including creosotes, etc.), 470; varnish materials (including shellacs), 651; paint materials, 1,258; lubricants, 1,025; soaps, nondrying oils and metal polishes, 643; inks and related office supplies, 442; balloon fabrics, 391; rubber, 498; leather, 25; textiles, 242; miscellaneous, 302.

The tests were made for very many Government bureaus and establishments and for States, municipalities, and private parties among which may be mentioned the following: Agriculture, 24; Commerce, 4,170 (this includes samples received from other divisions of the Bureau for chemical tests); Interior, 14; Labor, 2; Navy, 444; Post Office, 609; Treasury, 848; War, 1,510; Panama Canal, 932; General Supply Committee of the District of Columbia, 436; United States Shipping Board, 160; other Federal institutions, commissions, and committees, 54; State, municipal, and other institutions, 40; private parties, 29; foreign and allied commissions, 1.

Publications in Chemistry.

The following papers emanating wholly or in part from the chemistry division were published during the year:

Scientific Paper No. 369, The Vapor Pressure of Ammonia. Published also in Journal American Chemical Society, volume 42, page 206, 1920.

Glass to Metal Joints, published in Journal American Chemical Society, volume 42, page 1364, 1920.

Factors Governing the Structure of Electrodeposited Metals, published in Transactions American Electrochemical Society, volume 36, page 57, 1919.

Lead Plating from Fluoborate Solutions, published in Transactions American Electrochemical Society, volume 36, page 101, 1919.

Notes on Black Nickel Plating Solutions, published in Monthly Review American Electroplaters' Society, volume 6, page 14, 1919.

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Determination of Zirconium and Titanium in Zirconium Ores, published in Journal American Chemical Society, volume 42, page 1439, 1920.

The Use of Cupferron in Quantitative Analysis, published in Journal Industrial and Engineering Chemistry, volume 12, page 344, 1920.

The Detection and Determination of Glue in Rubber Goods, published in The Rubber Age, volume 6, page 109, 1920; India Rubber World, volume 6, page 216, 1920.

A New Method for the Determination of Sulphur in Oils, published in Journal Industrial and Engineering Chemistry, volume 12, page 482, 1920.

Circular No. 95, Composition, Manufacture, and Methods of Testing Inks.

Technologic Paper No. 154, The Determination of Cellulose in Rubber Goods. Also appeared in Rubber Age, volume 6, page 299, 1920.

Technologic Paper No. 162, The Extraction of Rubber Goods. Also appeared in Rubber Age, volume 6, page 445, 1920.

A New Hexabromide Test for Linseed Oil, published in Journal Industrial and Engineering Chemistry, volume 12, page 52, 1920.

Circular No. 84, Recommended Specification for Basic Carbonate White Lead, Dry and Paste.

Circular No. 85, Recommended Specification for Basic Sulphate White Lead, Dry and Paste.

Circular No. 86, Recommended Specification for Turpentine.

Circular No. 87, Recommended Specification for Zinc Oxide, Dry and Paste.

Circular No. 88, Recommended Specifications for Leaded Zinc Oxide, Dry and Paste.

Circular No. 89, Recommended Specifications for White Paint and Tinted Paints Made on a White Base, Semipaste and Ready Mixed.

Circular No. 90, Recommended Specifications for Red Lead, Dry and Paste.

Circular No. 91, Recommended Specification for Ocher, Dry and Paste.

Circular No. 93, Recommended Specification for Iron Oxide and Iron Hydroxide Paints.

Circular No. 94, Recommended Specifications for Black Paint, Semipaste and Ready Mixed.

The following are in preparation or in press:

Notes on the Use of Hydrofluoric Acid in Nickle-plating Solutions.

Specific Volume of Saturated Ammonia Vapor.

Preparation of Pure Ammonia.

Vapor Pressure of Carbon Dioxide.

Density and Expansivity of Sodium Chloride Solutions.

Formation and Prevention of Noncondensable Gases in Ammonia-absorption Refrigeration Machines.

Equilibria in the System Carbon Disulphide—Methyl Alcohol and Carbon Disulphide—Ethyl Alcohol.

Investigation of New Deoxidizers for Steel.

The Application of the Thermal Conductivity Method to the Automatic Analysis of Complex Mixtures of Gases.

A Thermal Conductivity Method for Gas Analysis. Thesis, University of Southern California.

Recording Gas-Analysis Apparatus in the Helium Plant at Petrolia, Tex.
The Inflammability of Jets of Hydrogen and Inert Gas.
The Determination of Aluminum as Aluminum Phosphate.
The Quantitative Precipitation by Ammonia of Phosphorus Pentoxide in Company with Alumina.
The Determination of Molybdenum in Steel.
The Volatilization Losses of Phosphorus Pentoxide During Operations Involving Fuming with Sulphuric Acid or Fusion with Pyrosulphate.
Sulphur in Petroleum Oils.
Comparative Tests of Porcelain Laboratory Ware.
The Carbonization of Oils.
Circular No. 38 (Revised Edition), Rubber Goods.
Slushing Oils.
Recommended Specification for Green Paint, Semipaste and Ready Mixed.

6. ENGINEERING PHYSICS.

Investigations relating to mechanics, sound, and properties of matter; testing and development of engineering instruments; performance standards of mechanical appliances; sound ranging; investigation of soundproofing properties of building materials; analysis and correction of acoustical defects of assembly rooms; elastic properties of diaphragms and springs; investigation, testing, and experimental development of aircraft instruments; aerodynamical testing and research.

ENGINEERING INSTRUMENTS AND MECHANICAL APPLIANCES.

Water-Current Meter Rating Station.

An important engineering service rendered by the Bureau is the furnishing of accurate calibrations of water-current meters. These instruments are used for the measurement of the velocity of the water in rivers, irrigation canals, and other open channels to determine the quantity of water discharged. Such data are essential in water-power development, irrigation, flood prevention and similar projects, but involve the use of a large body of still water, means for moving the instruments through the water at uniform speeds, and apparatus for recording the observations; an installation too extensive and costly to be undertaken by private enterprise. The Bureau rating station furnishes exceptional facilities for the study and calibration of instruments of this class. The station flume is entirely housed in and is operated throughout the year. During the past fiscal year 251 current meter ratings were made for different engineering branches of the Government, private engineers and water companies and for instrument manufacturers.

Calibration of Instruments.

During the past fiscal year a total of 175 instruments, in addition to current meters referred to above, were calibrated, including pressure gauges of various descriptions, anemometers, water meters, odometers, engine indicators and the like.

Hub Odometers.

At the request of the War Department, work is in progress to secure data on which to base standard performance specifications for odometers for Army motor trucks.

Tests of Thermostatic Heating Valves.

An investigation, previously undertaken at the request of the Supervising Architect of the Treasury Department to establish performance standards for thermostatic valves used on radiator outlets

in vacuum-heating systems, was continued to include tests of devices recently developed. Twelve valves of a new type or design were tested under working conditions during the past year.

Investigation and Tests of Fire Extinguishers.

At the request of the Steamboat-Inspection Service the investigation and testing of hand chemical fire extinguishers and similar apparatus submitted to that Bureau for its approval for use on vessels under its jurisdiction was continued. Sixteen devices of this character were tested for compliance with standards previously determined as a result of this work, or independently investigated when new types or principles of operation were involved.

Miscellaneous Tests and Examination of Appliances.

A variety of miscellaneous tests of mechanical appliances were made, among which may be mentioned physical tests of 16 samples of air-tight caskets under consideration by the War Department for overseas use; performance tests of acetylene-regulating valves; tests of air pumps, pressure-relief valves, automatic gas shut-off valves, gauge glasses, and similar appliances.

On several occasions inventions were studied and an opinion of their feasibility and value rendered at the request of the Inventions Section of the Army General Staff.

AERONAUTIC INSTRUMENTS.

The work of the aeronautic instruments section includes the investigation, testing, and experimental development of all types of aircraft instruments, such as altitude-measuring instruments, rate-of-climb indicators, engine speed and air speed indicators, navigating instruments and accessories, airplane and balloon pressure gauges, gasoline-supply gauges, inclinometers, banking indicators, turn indicators, bomb sights, and oxygen-control apparatus; also mercurial barometers, weather and surveying aneroids, and sphygmomanometers. There are also included the development of methods of testing, improvement in design, fundamental researches on the physical principles of such instruments, the study of their operation in actual service, and the determination of the corrections required for aircraft-performance tests.

Clearing House for Instrument Information.

During the past year there has been an increasing demand for scientific information relating to every aspect of instrument work. The aeronautic instruments section has served as a central agency for the coordination of such information which has been applied for by manufacturers and by representatives of the military, naval, and post-office aviation services, and not infrequently by delegations from foreign countries.

Study of Foreign Instruments.

A member of the section has been detailed to represent the Bureau abroad during the past year. He has established additional official contacts and pleasant cooperative relations with the aviation and scientific authorities in England, France, Italy, Belgium, and Hol-

land, and has collected, for official use by the Bureau, the latest European instruments and technical information. In return he has been able to place at the immediate disposal of the proper authorities abroad the current results of the Bureau's investigations. This exchange of technical data has been very much facilitated through the courtesy of the commercial attaché service of the Department of Commerce. The results of this work have been of considerable value and interest in this country in view of the relatively greater activity of aeronautic research and development in Europe.

Additions to the Instrument Collection.

Extensive additions have been made during the year to the Government collection of aeronautic instruments which is maintained by the Bureau of Standards. Among these may be mentioned a variety of German instruments for both airplane and balloon navigation and some of the latest instruments of British manufacture, including a gasoline-flow meter of novel design, a turn indicator, and a density meter for correcting air-speed readings.

Technical Publications.

A group of manuscripts with very full illustrative material has been nearly completed for publication through the National Advisory Committee for Aeronautics under the title "General Report on Aeronautic Instruments." In the preparation of this report the entire staff of the aeronautic instruments section and several experts from other divisions of the Bureau have cooperated. This report will form a fundamental contribution to the literature on aeronautic instruments and show quite completely the state of the art at the end of the war. A paper which will serve as a preliminary introduction to the foregoing material has been presented before the American Society of Mechanical Engineers and will be published in the transactions of the society for 1920. This paper deals with the general principles of construction, testing, and use of aeronautic instruments. The various types of instruments are systematically classified and briefly described. The principles involved in the different methods of testing are discussed and suggestions are given for securing the best results from instruments in practical use. The following additions have also been made during the year to the series of Aeronautic Instruments Circulars which are distributed in mimeographed form, with blue prints and photographs, for temporary use by the Government and authorized investigators: Pressure-Altitude Tables (fourth edition, revised and extended); Airplane Compasses; Investigation of Master Tachometers; Description and Theory of Rate-of-Climb Indicators; Average Results of Performance Tests on Airplane Tachometers; Design for Dummy Observer; Bureau of Standards Rate-of-Climb Indicator, Model No. 3. A French translation of the Descriptive List of Aeronautic Instruments Circulars was prepared and found useful by the Bureau's representative in his conferences abroad.

Material for Instruction Courses.

Photographic and descriptive material for use in courses of instruction on the subject of aeronautic instruments have been supplied at

the request of the Massachusetts Institute of Technology, the United States Army Air Service, and the Bureau of Navigation of the Navy Department.

Salvage of Aeronautic Instruments.

A statistical study is being made of the actual causes of failure in aeronautic instruments. Such facts are really the foundation for intelligent improvement of design in the future as regards the ordinary standardized service instruments with which all planes are equipped. During the past year the aeronautic instruments section of the Bureau has salvaged for the air mail service a collection of tachometers, magnetic compasses, radiator thermometers, air-speed indicators, and airplane pressure gauges. A quantity of barographs were submitted for salvaging by the air service of the Army, and a number of these instruments have been reconstructed so as to function over a higher range of altitude. The salvage problem consists of dismantling a certain number of damaged or defective instruments and putting them together, so as to form a smaller number of good instruments accurately readjusted and compensated for temperature.

Routine Testing.

The amount of testing done by the aeronautic instruments section during the past 12 months for outside agencies may be classified as follows:

5 mercurial barometers.
13 ordinary aneroid barometers.
38 altimeters.
57 barographs and altigraphs.
16 air-speed indicators.
20 tachometers or speedometers.
18 miscellaneous instruments, including airplane pressure gauges, thermometers, sensitive manometers, inclinometers, rate-of-climb indicators, and airship computing devices.

The testing done in connection with the Bureau either on developmental projects or the instrument collection has not been included in the foregoing summary.

Flight Tests on Aircraft Instruments.

In cooperation with the Army and Navy, the section has continued to make occasional flight tests on aeronautic instruments. Information often comes from the comparison of flight test results with laboratory results on the same instrument, which would not be readily apparent from either type of test taken by itself. Among the most interesting flights made by the members of the section during the 12 months just closed, may be cited a trip in the French dirigible at Langley field, the *Zodiac*, in which observations were made on the performance of a new type of air damped compass; a series of airplane observations, flying level at different altitudes and speeds, for the purpose of securing a practical check on the results of the laboratory experiments on air-speed indicators at reduced pressure; a series of flights for the intercomparison of different types of rate-of-climb indicators; and a flight for the practical demonstration of the "dummy observer," which was recently developed by the Bureau.

Conferences with Manufacturers.

Since it is the function of the Bureau of Standards to assist in building up American industries, including the instrument industry, the section has continued to confer with manufacturers from time to time during the year, although there has been no demand at this time for large-scale production. Some of the more important subjects which have been taken up during the year with the respective manufacturers are:

Diaphragm construction.
Improvement of thermographs.
Oxygen apparatus.
Special inks to withstand low temperatures.
Sphygmomanometers.
Aneroid barometers.

In this way the Bureau has cooperated with the manufacturers in regard to keeping up the quality of their product and has had available for the use of the aviation branches of the Government at all times an up-to-date survey of manufacturing resources in the instrument field.

Altitude Computation.

The past year has witnessed great popular interest in world's record altitude competition. The Bureau has cooperated with the Air Service of the Army and the Aero Club of America and all persons interested in formulating as definitely as possible the best procedure for determining the most probable altitude reached. The Bureau has also assisted in the selection and testing of the instruments themselves, which have to be of exceptional quality to afford reliable results in high-altitude flying on account of the mechanical strain and low temperature experienced.

Diaphragm Investigation.

This problem of research was mentioned in last year's report and has been continued. It was undertaken at the request of the National Advisory Committee for Aeronautics and is evidently one of the most important lines of investigation in progress in the section, because of the variety of different instruments for which thin, flexible diaphragms are necessary. Results have already been secured along five principal lines, namely:

1. The mathematical theory of irreversible effects which cause the lag in diaphragm instruments has been systematically formulated.
2. Charts have been prepared showing the relation between force and deflection for diaphragms of different sizes, thicknesses, and materials, and these results have been generalized by the method of dimensions so as to throw them into a useful form for practical design.
3. Further experience has been gained and information compiled regarding practical methods for spinning or forming diaphragms and building up diaphragm boxes.
4. Preliminary conclusions have been reached regarding the possibilities of mechanical seasoning by repeated stress.

5. A series of experiments has been completed in cooperation with the Geological Survey, using delicate optical methods for determining the experimental laws governing the departure from perfect elasticity of specimens of very thin sheet metal used for diaphragms. Five different alloys have been investigated, and these experiments should be continued.

Sphygmomanometers.

At the request of the medical department of the Army and of several manufacturers a systematic comparative investigation has been made of commercial sphygmomanometers, which are used in blood pressure determinattion in examining the physical fitness of aviators and for general physical examinations by the medical profession. The results of this work will provide a reasonable basis for specifications and have revealed the principal defects which ought to be improved in future development. Both diaphragm and mercurial types have been examined, and to facilitate the tests a precision mercurial standard has been constructed, which was designed with special reference to the needs of this class of work.

Direction Indicators.

A study has been made of the characteristic sources of error in the different types of instruments which are used for determining the direction of an aircraft, including gyroscopic and liquid inclinometers and banking indicators, gyroscopic and magnetic compasses, and turn indicators.

Navigating Instruments.

At the request of the National Advisory Committee for Aeronautics and also of the Air Mail Service of the Post Office Department, the Aeronautic instruments section has been compiling information regarding instruments available for aerial navigation in cloudy weather or at night, and over long distances. At the request of and in cooperation with the navigation branch of the Army Air Service this work will be actively continued and the development of new instruments taken up.

Altitude Effect on Air-Speed Indicators.

Experiments have been completed which will shortly be prepared for publication, through the National Advisory Committee for Aeronautics, on the change in the performance of Venturi tube airspeed indicators due to change in atmospheric conditions. The results show that certain instruments in common use are subject to a correction for the viscosity of the air which has not hitherto been taken into account. This result is of interest especially where the air speeds are comparatively low, as in dirigible work, or where exceptional precision is called for, as in performance testing of aircraft. A miniature wind tunnel has been used for this work which was so arranged that reduced pressures could be maintained corresponding to conditions at high altitudes. It is planned to continue the investigation next year so as to include the examination of additional types of instruments. The construction of new equipment for this purpose has begun.

German Aeronautic Instruments.

A report is in preparation summarizing the results of an investigation of the various types of German instruments which have been collected by the section, including the combination gyroscopic turn indicator and banking indicator, electric-resistance thermometer for dirigible balloons, and a remote indicating compass.

Dummy Observer.

The application of the moving-picture film for recording instrument readings during the flight of an airplane, referred to in the previous report, has been completed during the year and turned over to the Air Service. It consists of a group of especially selected performance test instruments suitably illuminated and arranged in a box with automatic timing control for the camera. It takes the place of an additional human observer on the airplane and affords records which are more accurate than those which could be obtained by the ordinary recording instruments.

Rate-of-Climb Indicator.

The Bureau of Standards rate-of-climb indicator, model No. 3, has been completed and successfully tested. This instrument reads directly the rate of climb in hundreds of feet per minute; its operation depends upon a capillary tube and an exceptionally sensitive diaphragm, dispensing entirely with the use of liquid. Specifications were prepared for the Balloon and Airship Division of the Army, on the basis of which a contract was placed for manufacturing a number of the instruments.

Precision Altimeter.

The large precision altimeter developed by the Bureau has passed its tests successfully, showing almost complete freedom from elastic lag. This design was based on the principle of making the diaphragm so very flexible in comparison with the spring that the quality of the diaphragm metal could not appreciably influence the result. A steel spring superior to the commercial grade was then prepared by the metallurgical division of the Bureau. A second model has recently been designed in which additional improvements are introduced. Such an instrument has been very much needed for performance testing of aircraft.

Turn Indicator for Airplanes.

A new type of turn indicator for aircraft has been developed by the gas-measurement section of the division of weights and measures. Turn indicators are extremely useful to aircraft flying in fogs, in clouds, and at night to enable the pilot to fly his craft in so nearly a straight line that his compass will function properly and to prevent him from unknowingly flying in a circle of such small radius that his machine will get out of his control. The particular type of turn indicator which has been developed depends upon the principle that, due to inertia, a jet of air issuing from a short tube fastened to the airplane frame will not change its direction relative to the earth at the same instant that the airplane does. Hence, by placing a suitable indicator in the path of the jet it should be possible to

detect instantly any deviation of the aircraft from a straight line. While this principle has not been made use of before in such instruments, trial tests have indicated that it is practical. It is very simple mechanically and will probably be quite inexpensive to manufacture. It is planned to publish a detailed description of this instrument in the near future.

Contrast Between War and Peace Activities.

The work of the aeronautic-instruments section during the war was directed mainly toward problems of quantity production and testing. The total volume of work called for is to-day fully as great as it was in the summer of 1918, but the character of the work has changed. The main activities now are along the three following lines: First, systematic investigations which will form the basis for scientific construction and performance specification in the future; second, gradual development of improvements in the standard service instruments by the scientific solution of fundamental difficulties, notably in the case of centrifugal tachometers; third, design and development of special instruments for aerial navigation and performance testing of aircraft. In all of this recent work, also, there has been a relatively greater emphasis placed upon instrument problems relating to dirigible balloons than was the case during the war.

AERODYNAMICAL PHYSICS.

Resistance of Projectiles at High Air Speeds.

Resistance measurements of projectiles have in the past been made through actual firing tests, in which the deceleration of the projectile was determined by measuring the successive time-intervals involved in the passage of the projectile through a series of screens. This method necessitates the measurement of short time intervals with great accuracy since the rate of change of the velocity is required in order to determine the deceleration. During the past year a series of direct measurements of the resistance of projectiles of various types has been carried out in cooperation with the Ordnance Department of the Army. The investigation has been conducted at the works of the General Electric Co. at Lynn, Mass., with the aid of powerful centrifugal air compressors manufactured by that company. The compressor delivered air under pressure to a large vertical standpipe 3 feet in diameter, fitted at its upper end with a suitably designed orifice 12 inches in diameter, through which the air expanded adiabatically. The resistance measurements were made in the air stream as it issued from the orifice.

The projectile to be measured was rigidly attached by its base to the lower end of a vertical spindle, which in turn was supported from a vertical piston in an accurately ground cylinder. The whole apparatus was supported on a horizontal stream-lined arm, so arranged that the projectile and its mounting could be swung into the air stream with the projectile pointing directly at the issuing jet. By varying the pressure in the cylinder the projectile could be made to float in the air stream. The observed differential pressure at this moment and the constants of the apparatus provided the necessary data for determining the resistance. A similar measurement with

the projectile in position below the spindle but supported from an independent mounting gave the correction for the resistance of the spindle.

With the equipment as described it has been possible to obtain resistance measurements at any desired air speed up to or slightly exceeding the speed of sound in air. Shadow graphs have also been obtained showing stationary sound waves in front and at the rear of projectiles held in the air stream, when the latter was moving past the projectile at a speed of 1,250 feet per second. The measurements made so far give promise of being of great value in the study of external ballistics and the work will be continued.

Wind Tunnel Measurements on Projectiles.

Supplementing the work described above, a series of measurements on the resistance of projectiles has also been conducted in the high-speed wind tunnel at the Bureau, in which a maximum wind speed of 250 feet per second can be attained. This work has included the direct measurement of the head resistance of the projectile both by direct and indirect methods. In the direct measurements, the projectile was suspended from wires and its deflection downstream at various wind speeds was determined. Suitable correction for the supporting wires was, of course, applied. In the indirect measurements, the pressure was determined at various points over the surface of the projectile, and especially across its base, and the resistance calculated by integrating the axial component of pressure over the entire surface of the projectile.

Head Resistance and Stability of Aircraft Bombs.

In cooperation with the Ordnance Department of the Army the aerodynamical characteristics of a series of wooden models of bombs, geometrically similar to, or modifications of the Mark II high-capacity drop-bomb, have been determined in the 54-inch wind tunnel during the past year. A few of these determinations were checked in the 36-inch wind tunnel of the Bureau, and in the 8-foot tunnel at the Washington Navy Yard. While the relative magnitudes of the air forces and moments on different bombs as determined in the wind tunnel are of value in ballistic problems, it is not justifiable to extrapolate the head resistance to high speeds in order to obtain the terminal velocity of a bomb which approaches the velocity of sound. The terminal velocity computed from the head resistance as determined in the wind tunnel has been found to be about 30 per cent greater than that measured in the vertical fall of a bomb from a balloon. The oscillations of the bomb, starting with an initial amplitude of 10°, lead to a sufficient increase of the average head resistance to account for a large part of this difference.

A stream-line bomb model often has a lower head resistance than the mounting supporting it. Even when all corrections are made for the effect of mounting, the head resistance as determined by the bifilar suspension method is at least 10 per cent greater than that determined by balance measurements. The measurement of the head resistance of the Mark III model on the Bureau's aerodynamical balance checked within 4 per cent with balance measurements in the navy-yard 8-foot tunnel, notwithstanding the fact that the Mark

III model is the largest model that is permissible in the 54-inch tunnel.

The Mark II model was cut in two at its maximum cross-section and cylinders varying in length from one to four times the diameter of the bomb were inserted. The bomb with an insert two diameters long has a smaller head resistance than the same bomb with an insert one diameter long. Check runs in the 36-inch wind tunnel with bifilar suspension yielded the same relative results.

Logarithmic decrements of the oscillations of the Mark II model were determined in the 54-inch tunnel for several wind speeds. For drops from elevations up to 2,000 feet, for which data on oscillations in free fall were available, this linear damping effect is small. The greater part of the damping is due to the increased restoring torque of the fins with increase of speed. The calculation of the period of oscillation, even from incomplete equations of motion, check the results obtained from dropping tests to about 30 per cent.

Aerofoil and Airplane Model Tests.

The aerodynamical characteristics of a series of biplanes of varying stagger and decalage have been determined in the 54-inch tunnel. One wing of the combination was R. A. F. 15, and the other the symmetrical form of H. F. Parker's variable camber wing. These biplane combinations, in general, show less biplane interference than where both wings are of the ordinary type. The report on these tests has been submitted to the National Advisory Committee for Aeronautics, with whom the Bureau cooperated in the work, for publication.

Longitudinal stability tests were carried out on two models of the Johns multiplane (seven wings) of the American Multiplane Co. The determination of the tail plane characteristics gave significant results and showed the great desirability of further model experimentation on this type of design.

Longitudinal stability tests were made on the biplane model submitted by Ensign G. B. Linderman, both with ground landing gear and seaplane floats. The forces on the stabilizer-elevator group were determined, and an estimation of the performance of the full scale machine made, using the land-type landing gear. In a later series of tests a complete longitudinal and lateral static stability determination was made.

Complete static stability tests were carried out on a model of the internally-braced monoplane of the American Aircraft Co. Determinations were made of the force and moment components referred to three axes fixed in the model at four angles of pitch and at varying angles of yaw up to 20°.

Air Resistance of Spheres.

The sphere is a difficult body to investigate aerodynamically on account of the turbulence it produces, but its geometrical form is such as to make the determination of its resistance by several different methods possible. The investigation has included a measurement of the resistance (1) by a balance method, in which the sphere was supported on a spindle; (2) by a deflection method, in which the sphere was suspended from wires; (3) by a dropping method, in which the deflection of the sphere when falling freely across a wind stream was

determined. This last method involves no correction for supports, while in the other two methods the resistance of the spindle and supporting wires must be determined.

The influence of wind-tunnel conditions on air-resistance measurements has also been investigated by the application of the principle of dynamical similarity to observations on spheres of different diameters.

Interesting results have been obtained relative to the effect of the roughness of the surface of a sphere on its resistance. It has been found that roughening the surface lowers the so-called critical speed, at which point a marked change occurs in the character of the flow about the sphere, accompanied by a large reduction in the resistance coefficient. The result is that at certain wind speeds a sphere with a smooth and highly polished surface offers a greater resistance to the wind than a sphere of the same diameter with its surface roughened or "brambled" like a golf ball.

Roof Ventilators.

At the request of the War Department and the industry a test was made in 1918 to determine the relative efficiency of various types of roof ventilators, which are supposed to produce a suction in the pipe to which the ventilator is attached when the wind blows across the ventilator head. At the suggestion of representatives of the American Society of Heating and Ventilating Engineers, these tests are now being extended to include the efficiency of ventilators at lower air speeds than were used in the earlier tests. A study has also been made of the character of the flow around ventilators of various types, with a view to improving their efficiency. The resistance offered by different types of ventilating heads when the flue is functioning simply as a chimney has also been determined. A report on the subject is in preparation.

Measurement of Low Air Speeds.

The work described above necessitated the measurement of air speeds below 5 feet per second in a pipe 16 inches in diameter. A simple device was developed in the laboratory which met this requirement satisfactorily. It consisted of a very small, straight wire 12 inches long, hanging freely in a horizontal pipe and fastened at its upper end to a small horizontal staff supported on jeweled bearings. The bearing block was supported from the top of the horizontal pipe, the staff being normal to the wind direction. The deflection of the wire by the wind stream was observed through a window in the side of the pipe. The apparatus was calibrated directly by means of an orifice 2 inches in diameter temporarily introduced into the pipe, the wind speed being determined by the drop in pressure through the orifice. The equipment has proven very useful for measuring low air speeds in horizontal pipes.

SOUND.

During the year the sound laboratory has made very satisfactory progress in developing equipment for its peculiar kind of work. This type of equipment is in general not commercially available, and must be designated and constructed in the laboratory in which it is to be used.

Acoustic Properties of Building Materials.

In response to an increasingly insistent demand for information on the sound transmission and absorption properties of building materials, an investigation having for its object the collection of data covering the most common materials was begun. In connection with the construction of hospitals and hotels the Bureau has been asked to state what materials would permit the use of walls of minimum thickness consistent with adequate acoustical insulation. Questions of this kind are confronting the architect almost daily, and it is the aim of the Bureau to continue the investigation so that reliable information regarding the acoustical properties of present-day building materials may be available.

Acoustic Properties of Assembly Rooms.

Considerable difficulty has been experienced in various Federal court rooms and other assembly rooms of the Government departments, owing to inability of auditors to hear comfortably. This difficulty is largely due to reverberation; that is, the continuation of the sound after the source has ceased to emit. In some cases it was found that the sound heard at any instant included from 10 to 20 preceding syllables, leading to annoying confusion. The Bureau has cooperated with the Supervising Architect of the Treasury Department in correcting the difficulties in existing structures and in preventing them in other instances through suitable design in advance of construction. Four cases of the former kind and two of the latter were handled in the course of the year for the Treasury Department alone.

The Triode Drive of Tuning Fork.

The electrically driven tuning fork has, in recent years, come into more frequent use as a small-scale time standard. The contact method of drive has been a frequent source of trouble, particularly when the frequency of the fork is 500 cycles or higher. A vacuum tube method of drive has been developed at the Bureau, which insures the continuous operation of the fork with a relatively large amplitude and with a remarkable uniformity of period.

Precise Measurement of Small Time Intervals.

The success attained in driving a tuning fork continuously at a very constant rate opened the way for making measurements of time intervals with a high degree of accuracy. Using a 500 cycle fork, timing indices one-thousandth of a second apart were obtained on a moving film, successive indices being spaced several centimeters apart. This combination constitutes a chronograph which permits measurements to at least hundred-thousandths seconds for approximately $1\frac{1}{4}$ seconds, or to ten-thousandths seconds for 25 to 30 seconds. This chronograph has been used to make the following measurements, which illustrate its range of availability: (1) Measurement of projectile speeds up to 2,800 feet per second over distances of 10 to 20 feet; (2) determination of the acceleration characteristic of a small turbine attaining a speed of 6,700 r. p. m. in 3 seconds from rest; (3) measurement of the time-lag between a control clock and the controlled radio time signal, the lag being of the order of seven-

hundredths of a second: (4) measurement of the operation time of photographic shutter.

Cooperation with the War Department.

Technical data on the parabolic sound reflector used for locating aircraft were obtained for the Engineer Corps of the United States Army. The aim of this work, which is still in progress, is to obtain fundamental data upon which efficient design of such an instrument can be based.

Substantial assistance was given the Technical Staff of the Ordnance Department in a program of work on air resistance of projectiles.

SPECIAL INVESTIGATIONS.

An investigation of the possible fuel economy of jet propulsion for aircraft was undertaken for the Army Air Service and gave unexpectedly interesting results. At flying speeds corresponding to those obtainable at the present time, jet propulsion would require a much greater fuel expenditure than a motor-driven air screw. On the other hand, the relative efficiency of jet propulsion increases with the flying speed and this novel method of propelling an airplane may have important military applications in short flights where fuel economy is of secondary importance.

A study was made of the conditions that must be fulfilled in order that model experiments on the resistance of ships to submarine explosions may give reliable results for designing purposes. This was undertaken in consequence of a communication on the same subject from the Italian Government. A paper on the subject will soon be ready for publication.

A paper dealing with some of the obscure points in the theory of dimensions has been completed and a book on this subject is in course of preparation. The theory of dimensions provides an effective means of attacking many physical problems and is indispensable in experiments involving models. No general treatise on the subject is at present available.

7. STRUCTURAL, ENGINEERING, AND MISCELLANEOUS MATERIALS.

Nearly all the materials ordinarily used in industrial work are investigated and tested by this division. These include metals of all kinds, when made up into structures or parts of structures, wood, cement, concrete, stone and sand, leather, rubber and composition materials used in place of these, textiles, paper, lubricating oils, lime, gypsum and sand-lime brick. The work of this division is of such a nature that very often the investigation of a structural material requires the study of the manufacturing process by which it is produced, and for this reason the equipment includes, besides a complete assortment of testing machines, an experimental rubber mill, textile plant, paper machine, cement plant, etc.

METALS.

In these laboratories measurements are made of the resistance of engineering materials, particularly of metals and wood, under tensile, compressive, and torsional stresses. The fatigue and impact resistance of materials, as well as their hardness are subjects of careful study. Especially is attention given to the design of testing apparatus and to testing methods in general in order that these

may be improved. The properties of new materials are determined so that they may be used successfully by the other Government departments, the industries, and the public. Attention is given to the alloys of aluminum having low weight, because of their importance in the construction of aircraft. Engineering structures are designed and tested to determine the construction most suitable for a given purpose. Many of these are tested under load to observe the behavior of their parts. Among these tests may be included ones upon machine and airplane parts, buildings, and cranes.

Strain Gauge Measurements of 350-Ton Crane.

The Navy Department has recently built at Philadelphia a 350-ton fitting out crane for placing heavy objects, such as turrets, in position on board ships. This crane, one of the largest in the world, attracted a great deal of attention from engineers and the general public during the latter part of 1919. This structure is statically indeterminate, and therefore stresses in the members can not be calculated. At the request of the Bureau of Yards and Docks of the Navy Department, a study was made of several compression members of this crane, using a strain gauge to measure the change in length of these members under load. From these readings the change in stress was calculated. The work was carried out during a very severe winter. It was necessary to erect platforms near the top of the structure, exposed to high winds, rain, and sleet. In spite of these difficulties the results were satisfactorily consistent.

Efficiency Tests of Oxyacetylene Torches for Welding and Cutting.

During the recent war the War Department found that it was unable to prepare specifications for the purchase of oxyacetylene torches, due to the lack of sufficient data concerning apparatus of this kind. On account of the need for securing the best kind of cutting and welding equipment, this Bureau was requested to make efficiency tests of the commercial torches, about fifteen in number. The tests were made to determine the amount of gas used in welding one-half and three-fourths inch steel plate and in cutting one-half inch, 2 inch, 6 inch, and 10 inch steel. Data were secured upon the ratio of the gases used, the conditions under which flash-back occured, and the general suitability of the apparatus as to safety, strength, etc. It was necessary to spend several months in preparing the apparatus as the amount of gas was determined by weight and also by a carefully calibrated orifice flow meter. Manometers were used to measure the pressures. Recording pressure ganges were also used to secure a continuous record. The report upon the results is now in preparation and will be furnished to the Army for their use with suggestions on purchase specifications of these torches.

Fireproof Airplane Wings.

The fact that airplane wings and fuselage constructed of wood and covered with doped fabric are highly inflammable has been the cause of many deaths when accidents occurred in flight. The possibility of death from this cause is believed to greatly lower the morale of the Air Service. Metal has now been proven suitable as

a substitute for wood in an airplane structure. In order to produce a completely fire-proof airplane, it will be necessary to secure a fire-proof covering for the wings in place of the fabric at present in use. A study of the materials which can be used shows that corrugated metal such as used in the Junker airplane is satisfactory. Its weight, however, is several times that of the present fabric.

Thin sheet metal stretched over the structure like a fabric appears to be unsuitable due to its low tear resistance. If used, it might readily rip sufficiently to cause disaster if injured by a bullet. If this material is reinforced by wire mesh its tear resistance would be satisfactory. Metal wire mesh or screen could be used if provided with a satisfactory covering so that it would present a smooth surface. Experiments have shown that a paint film may be applied to a wire mesh having openings of one-tenth inch if thin paper is applied to one side. A paint film of this kind is sufficiently fire resistant to allow gasoline to be burned from the surface without propagating the flame.

The position of the pilot in most planes is such that his vision is greatly restricted by the wings and other portions of the structure. A transparent covering for the wings would prove valuable if used for several feet near the cockpit. Sheet celluloid is highly inflammable but cellulose acetate, such as used for fireproof moving-picture film, if supported by a wire mesh, would probably prove satisfactory. The weight, however, would be much greater than the present fabric wing covering.

Tests have been made to determine the tensile and bursting strength as well as the tongue and tear resistance of many types of wing covering. The results are given in a preliminary report, Letter Circular VII–1–12, giving the mathematical theory and a survey of the possible materials.

Effect of Acid on Rope.

Muriatic acid is often used to clean the stonework of buildings and monuments. If the acid comes in contact with the rope supports of the swinging staging required by the workmen, the strength of the rope is greatly impaired. Many accidents resulting in loss of life have occurred from this cause.

It was suggested that a protective compound which has been found successful in protecting metal work from the deteriorating influence of acid be used on rope. Tests were made by exposing the specimens of rope to fumes of muriatic acid and also by dipping them in acid solutions. The tensile strength was then measured. It was found that in many cases rope of three-fourths inch in diameter could be broken in the hands. Apparently the compound offered no protection.

Metallic Bellows.

The Army wish to use metallic bellows in connection with the construction of ordnance, but at the present time are unable to obtain them. One of the officers engaged on this work devised a method of forming the bellows and at the request of the Army this method was tried at the Bureau of Standards. The results together with a number of suggestions for improvements were embodied in a report.

Specimens of the bellows obtained were also supplied to assist in perfecting the apparatus which was demonstrated to representatives of the Army interested in this problem.

Cause of Failure of a Railroad Bridge.

At the request of Iowa State authorities, the failure of a railroad bridge which had been in service for 30 years was studied. Consideration of all the information which could be obtained, supplemented by tests of portions of the material, led to the conclusion that the design of the bridge was unsuitable for the heavy loads which it had been carrying in recent years. The spacing of the rivets was less than that allowed by good practice at the present time, a feature which emphasizes the necessity of including the rivet spacing in structural specifications. The material near the failure showed that it had been repeatedly overstressed, and this was probably the immediate cause of failure of the bridge.

Mexican Woods.

The United States consul at Mazatlan, Sinaloa, Mexico, submitted 32 specimens of wood for determination of their physical properties. They were chiefly the heavy hard woods which would receive a high polish. The local names for many of them were used, as it was impossible to find their botanical descriptions.

The tests included the moisture content, and the strength in compression and cross bending. The results showed that many of them had considerable commercial value if they could be obtained in sufficient size at reasonable cost.

Strength of Struts for Flying Boats.

In preparing designs for large flying boats similar to those which recently crossed the Atlantic, several types of struts were under consideration. About 15 specimens, prepared by the Navy Department and by manufacturers of wood veneer, were submitted for compressive tests to check the accuracy of their computed strength. The inconsistency of the results led to over 100 tests of the wood of which they were made. These showed a wide variation in the strength of the material but a direct relation between the strength of the wood and that of the strut made from it, as the struts having the highest strength were constructed from exceptional material and the weak struts from material having a low strength. When the modulus of elasticity of the wood was used in Euler's column formula, values were obtained which agreed closely with experimental results on the struts.

It was found also that some of the struts were made from basswood. The strength of these would have been much greater if spruce had been used.

Experimental Data for Design of Autofrettage Guns.

The usual method of constructing large guns by shrinking of one tube or hoop upon another is difficult and expensive. Recently a method, successfully used in France and known as "autofrettage," has been developed, by which the desired initial stresses in the gun are produced by overstressing it by internal hydraulic pressure. In

this process much of the material is stressed beyond its elastic limit. As this is unusual in engineering practice, few experimental data are available for design work of this kind.

Experiments were therefore made for the Ordnance Department of the Army to determine the relation of the lateral deformation to the longitudinal deformation upon steel specimens of varying cross sections subjected to both tensile and compressive stress which considerably exceeded the elastic limit of the material.

Several different methods were tried before one was found which gave results of sufficient accuracy. A large number of observations were made and the results indicate that much information of value to engineers and others would be obtained by a more extensive investigation along this line.

Bearing Pressure on Ball and Roller Bearings.

Bearings for the trunnions of large guns should have little friction, but must withstand heavy loads when the gun is fired. The use of ball and roller bearings is desirable, but little information is available regarding the maximum loads for bearings such as these, which move slowly and infrequently.

Tests were made at the request of the Navy Department upon commercial steel balls and rolls to measure the area of contact between the ball or roll and the loading surfaces, the amount of compression and the resistance to motion for both flat and cylindrical bearings. It was found necessary to design and construct special apparatus, and the tests are still in progress.

Strength of Metal Fence Posts.

At the request of the Indian Service, several commercial types of steel fence posts suitable for use on Indian reservations were tested for strength and resistance to impact.

The selection of a post suitable for the soil, climate, and service conditions, which vary widely, is a matter of importance, due to the large number of posts purchased each year. The report included, in addition to strength tests, recommendations upon the location of the "spade" and other details.

Fatigue Resistance of Copper and of Iron Tube.

Many forced landings of mail planes in the Postal Air Service are caused by fracture of the copper tube connecting the feed tank with the engine. The suggestion that wrought iron would probably have a greater fatigue resistance and that tubes made of this material would therefore be more durable than copper led to comparative tests in the rotating beam-testing machines in the materials laboratories.

The results were not conclusive, as the testing machines were unsuited to specimens of such small diameters. The average of the values obtained for each showed a somewhat greater fatigue resistance for the iron tubes, even though they had very rough surfaces. Several failures occurred where the tube was stamped with the trade name. If iron tubes could be obtained having the smooth surfaces and uniformly thin walls of the copper tubes, it is probable that they would prove much more serviceable than those now in use.

Joint Committee on the Investigation of Sulphur and Phosphorus in Steel of the American Society for Testing Materials.

The staff of this section is represented on the subcommittee on statistics of this committee. This subcommittee has spent much time in seeking material which has failed in service and which either shows normal or high sulphur and phosphorus content. For this purpose personal visits have been made to the Army and Navy representatives in a position to supply this material or any information regarding it. The representatives of some of the leading railroads and automobile manufacturers have also been consulted.

A number of specimens have been obtained from the railroads, but none from the other organizations. This material will be submitted to chemical and physical tests. A bibliography upon this subject has been prepared and distributed.

Committee on Heat Treatment of Carbon Steels of the National Research Council.

This committee is preparing and testing carbon steel specimens to determine the physical properties which can be obtained by heat treatment.

Cooperating with the other members of the committee, physical tests have been made in these laboratories upon about 50 specimens and the results reported to the chairman of the committee.

Safety Code for Elevators.

The staff of this section has, during the year, spent considerable time in cooperation with the electrical division and a committee of the American Society of Mechanical Engineers in the preparation of a safety code for elevators.

Numerous valuable suggestions have been submitted for the consideration of the committee, many of which have been adopted. A large amount of time was also devoted to editorial revision of the manuscript before publication in order to secure the best possible form of presentation.

Methods of Testing Hardness of Metals.

This section through representation on the committee on hardness-testing machines of the National Research Council has devoted considerable time to the problems before this committee. Several meetings have been held and plans perfected for carrying on research work by individual members of the committee in their laboratories.

The section has designed and made drawings of apparatus for calibrating the loading of the Brinell hardness-testing machines. These are now being considered by the committee.

Materials for Aircraft.

A member of this section, as secretary of the committee, has prepared programs for the meetings of the committee on materials for aircraft of the National Advisory Committee for Aeronautics. The use of duralumin in airplane construction has been considered, particularly with reference to the well-known Junker all-metal plane, constructed in Germany. Several meetings have been held for the preparation of specifications of stream-line wire for airplanes. This subject has received careful consideration by the committee and much experi-

mental and other work done in preparing a specification which would insure reliable material.

Development of Remote Reading and Recording Electrical Strain Gauges.

During the war the activities of the section on electrolysis prevention of the electrical division were largely diverted to various military problems, especially those arising in connection with the location of hostile batteries by sound ranging. An important element in this problem was the development of suitable electrical devices for recording the arrival of the sound waves at different points. The recording devices considered and developed for this purpose appeared to have so many possible uses that further work on them seemed advisable, and considerable time has been given particularly to the development of recording strain gauges or extensometers.

Instruments have long been available for application to structural elements to indicate the steady stress caused by dead loads on the structure, but until recently no progress has been made toward making these instruments recording. Quite recently two recording strain gauges have been developed elsewhere, but both of these are subject to the disadvantage that the whole of the apparatus must be mounted directly on the element under test, thus making it practically impossible to use them on any members not readily accessible. So far as the Bureau is aware, no progress whatever has previously been made in securing a remote recording strain gauge, and the work of the Bureau in this field has been strictly of a pioneer character.

The objective in this work has been to develop extensometers which shall be remote reading and remote recording so that relatively small parts may be placed on the structural members under observation, the bulk of the equipment being placed at some more convenient and accessible location, and also to make an instrument capable of recording transient stresses due to live loads. An incidental object has been the measurement of initial stresses due to the weight of the structure itself.

A number of different physical principles have been studied with a view to their use in the construction of gauges. The instruments on which more or less experimental work has been done include contact resistance devices, split core transformers, capillary tube instruments, vibration type of instrument, and bismuth wire instrument. Very promising results have been obtained and some instruments are now being given a practical trial, although much development work remains to be done.

The field of usefulness for apparatus of this type, not only on airplanes, but on bridge members and structures of many kinds, is very great, and it is highly desirable that these investigations be carried on until the apparatus can be made available for the wide variety of uses to which it is adapted.

Special Tests.

The protection of wood members of an airplane structure from moisture is important, as the strength may be reduced to one-half that of dry wood and the weight is also greatly increased. To find the actual condition which existed in seaplanes in service the Navy Department submitted specimens of wood cut from planes that had been in service at Chatham, Mass.; Key West, Fla.; Great Lakes Training

Station, Ill.; and Pensacola, Fla., for determination of the moisture content and specific gravity.

An artillery wheel formed from sheet steel was tested for the artillery division of the Ordnance Department of the Army. The results showed low strength due to the few welds which secured the rim to the wheel.

Summary of Tests.

The following statements show various materials tested by this section during the fiscal year ended June 30, 1920, together with the number of specimens of each type:

Metals.

Iron and steel:	
Cast iron	15
Steel	1,115
Total	1,130
Aluminum and aluminum alloys:	
Aluminum alloy	25
Aluminum alloy, duralumin	35
Aluminum alloy, lynite	36
Total	96
Copper, brass, and bronze: Bronze	245
Miscellaneous metals and alloys:	
Bearing metal, "cop-led"	9
Dental amalgam	6
Electrolytic nickel and copper	40
Total	55

Wood.

Airplane	110
Columns	6
Auto loading blocks	5
Paper roll cores	2
Field desk interiors	2
Total	125

Fiber rope and wire rope.

Rope, manila	73
Aircraft cord	4
Duracord	1
Parachute cord	1
Cordage	6
Cotton twine	1
Tarred lanyard	2
Tarred marline	2
Wire and wire rope	118
Wire cable	4
Total	212

Other material.

Bakelite insulating material	16
Electrosote insulating material	18
Total	34

Calibration of testing machines.

Riehle torsion testing machine	1
Riehle universal testing machine, 50,000 pounds	1
Riehle testing machine, 100,000 pounds	1
Scott horizontal testing machine	1
Schopper tensile testing machine, 1,000 kilograms	1
Olsen chain testing machine, 2,000,000 pounds	1
Total	6

Miscellaneous.

Bayonets	4
Belt, leather	1
Bolts and nuts	38
Bomb lugs	12
Chain link	6
Clamp	3
Drills	3
Fiber, hard horn	8
Firing pin, 240-millimeter howitzer	8
Glass, panes	44
Glass, bottles	354
Hacksaw blades	29
Hand grenade bodies	24
Hard rubber storage battery cases	6
Hinges, strap	2
Hook, metal	2
Jacks	2
Knives, butcher	2
Lenses	82
Light structural material	5
Locomotive packing ring	10
Machetes	8
Meat cleaver	1
Motor truck valve	1
Nut locks	27
Paper clips, brass	20
Paper scales	16
Picture film	1
Piston rings	1
Pneumatic tire	1
Redmanol	4
Red fiber	1
Rivets	10
Screws	39
Seals, Acme	6
Seals, Asbo	1
Seals, baling	23
Seals, Brooks	4
Seals, Signode	20
Shell rotating band	3
Shells	2
Spectacles	16
Spring	1
Strapping, box	2
Storage battery cases, vulcanized rubber	48
Tire base bands	1
Torpedo propellers	4
Turnbuckle	1
Welded specimens	500
Total	1,407
Grand total	3,310

Material Tested for Other Divisions of the Bureau of Standards.

Division I:
- Lenses.
- White hard horn fiber.
- Vulcanized-rubber storage-battery cases.
- Steel spring.
- Telegraph wire.
- Electrosote.
- Magnet wire.
- Bakelite.
- Hard-rubber storage-battery cases.
- Bronze wire rope.

Division II: Screws.

Division V:
- Hard horn fiber.
- Electrolytic nickel and copper.
- Aluminum alloy rivets.

Division VII:
- Redmanol.
- Picture film.
- Calibration of testing machines.
- Rope.
- Calibration of apparatus.

Division VIII:
- Welded specimens.
- Bronze.
- Locomotive packing rings.
- Bearing metals.
- Cast iron.
- Firing pins.
- Steel (nickel, gun barrel, rifle barrel, carbon and chrome vanadium).

Storeroom: Paper scales.

Materials Tested for the War Department.

Air Service:
- Light structural material.
- Balloon cable.
- Box strapping and seals.
- Turnbuckle and strap.
- Metal hooks.

Engineer's Office: Skein bolts.

Field Medical Supply Depot:
- Signode strapping and seals.
- Acme seals.

Inventions and Experimental Section:
- Aeroplane guy wire.
- Aluminum alloy-lynite.
- German rifle-barrel steel.
- Bayonets.

Motor Transport Corps:
- Steel.
- Motor-truck valve.
- Piston ring.
- Nut locks.

Ordnance:
- Shell-rotating band.
- Hand-grenade bodies.
- Steel bars.
- Steel bolt.
- Shells.
- Bomb-suspension lugs.
- Hard-drawn brass wire.

Purchase, Storage, and Traffic:
- Rope.
- Clamps.
- Butcher knives.
- Meat cleavers.
- Field-desk interiors.
- Baling seals.

Quartermaster Corps: Steel-tire base bands.

Materials Tested for the Navy Department.

Bureau of Construction and Repair:
- Moisture content and specific gravity of airplane wood.
- Aluminum and aluminum alloys.
- Duralumin, acerial, Huron metal, lynite.
- Steel forgings.
- Nickel steel tube.
- Aluminum-alloy rivets.
- Parachute suspension cord.

Bureau of Ordnance:
- Aircraft cord.
- Steel test bars.
- 5 and 6 inch steel diaphragms.

Naval Gun Factory, Washington:
- Calibration of testing machines.
- Torpedo propellers.
- Alloy-steel springs.

Navy Yard, Boston: Calibration of 2,000,000-pound chain machine.

Materials Tested for Other Branches of the Government.

Department of Agriculture:
- Forest Service—Telephone wire.
- Bureau of Public Roads—Steel reinforcing rod.

Department of Commerce:
- Bureau of Lighthouses—Glass.

Department of Interior:
- Bureau of Mines—Steel test bars.
- Geological Survey—Duracord.

Government Printing Office: Paper-roll cores.

Panama Canal Commission:
- Drills.
- Structural steel.
- Paper clips.
- Wire.
- Trolley wire.
- Hacksaw blades.
- Chain links.
- Manila rope.
- Bolts and nuts.
- Machetes.

Panama Canal Commission—Contd.
Tarred lanyard and marline.
Bronze-wire cable.
Steel cable.
Cotton and torpedo twine.
Superintendent State, War, and Navy Building:
Cast iron.
Wood columns.
United States Railroad Administration:
Welding wire.
Nut locks.
Riehle torsion machine.
Steel.
United States Shipping Board, Emergency Fleet Corporation: Steel castings and steel bars.

Materials Tested for Commercial Organizations.

Ultra glass.
Plain glass.
Bottles, glass.
Jacks.
Steel.
Bronze.
Spectacles.
Auto loading blocks.
Wedge bolt.
Strap hinges.
Calibration bars.
Rope.
Leather body belt.
Turbine studs.

Publications.

The following is an enumeration of the publications which were prepared by this section:

Technologic paper No. 150, Physical Tests of Motor-Truck Wheels, by Charles P. Hoffmann.

Technologic paper No. 151, Load Strain-Gauge Test of 150-Ton Floating Crane for the Bureau of Yards and Docks, by Louis J. Larson and Richard L. Templin.

Technologic paper No. 152, Investigation of the Compressive Strength of Spruce Struts of Rectangular Cross Section and the Derivation of Formulas Suitable for Use in Airplane Design, by James E. Boyd.

The Effects of Sulphur and Phosphorus on the Properties of Steel, a bibliography on the subject for the Committee on Phosphorus and Steel in Steel.

Fireproof and Transparent Airplane Wing Coverings. Letter Circular VII–1–12.

Report of Dimensions and Tolerances for the Cross Section of Streamline Stay Wire. Letter Circular VII–1–16.

The manuscript for the circular "Compiled Tables of Physical Properties of Materials" is now ready for the printer. These data have been submitted to a number of engineers and others for criticism and revised in accordance with the suggestions which have been received. The requests for these data indicate a need for this information which is supplied by no other publication at the present time.

CEMENT, CONCRETE, STONE, GRAVEL, AND SAND.

This section is concerned with the investigation and testing of cement and allied materials for construction purposes, the development of new methods of testing, improvement of apparatus for testing, the preparation of specifications covering cement and similar construction, development of new uses for cement products, the distribution of knowledge concerning their use, and with the design and fabrication of cement, concrete, and similar structures. The Bureau acts as a testing laboratory for practically all the cement used in the Government's construction work, as far as its facilities permit.

Test of a Concrete and Hollow-Tile Floor Reinforced in Two Directions.

It is believed that the test described below is the most elaborate one of a full size floor structure ever carried out. The expense of the work was largely borne by J. J. Whitacre of the Whitacre-Greer Fireproofing Co., of Waynesburg, Ohio.

The purpose of the test was to obtain data which would afford a basis for the design of a two-way reinforced concrete and hollow tile floor system. Mathematical analysis indicates the necessity for stronger construction than that which has been found satisfactory as the result of tests. This has led to a controversy between those who placed full confidence in analysis and those who believe in ignoring the analysis and designing solely on the basis of test results. The test here described was planned so as to eliminate the sources of dispute which have placed test results in question and have thus led to the above-mentioned controversy.

For the purpose of obtaining the data desired a large slab was constructed upon which strain measurements were taken on approximately 900 gauge lines in the reinforcement, 500 gauge lines in the concrete and 75 gauge lines in the tiles. Deflection was observed in 40 places.

The slab is 117 feet 6 inches long and 50 feet wide, and is divided into 18 panels. Six of these panels are 16 feet square, six are 16 feet by 19 feet 3 inches, and six are 16 feet by 22 feet 6 inches. These panels are supported by reinforced concrete girders, which are generally 12 inches wide. The slab, whose total thickness is 6 inches, is made up of 6 by 12 by 12 inch clay tiles laid in such a manner as to form rows in two rectangular directions with 4-inch ribs of reinforced concrete between each two rows of tiles. The ends of the tiles were left open, allowing a small amount of concrete to enter the cells so that they form an integral part of the slab. Each concrete rib throughout the slab has as reinforcement one $\frac{1}{2}$-inch plain round bar extending the full length of the rib.

The slab was first loaded with a uniformly distributed load until the yield-point stress in the reinforcement over the edges of the panel was reached. The load was then shifted to give higher stresses at other places in the slab. Although it had been planned to apply enough load to cause failure it was not possible to pile the load high enough to bring about complete destruction of the slab. Approaching failure was indicated by the fact that the stress in the reinforcement had passed the yield point in many places. No indication of compression failure in the concrete or in the clay tiles was found. In such constructions it is generally assumed that the tile is only a space filler which lightens the construction, but it was found here that it contributed in an important manner to the strength of the structure.

With respect to the manner in which the stresses were distributed through the slab and with respect to a comparison of the behavior of square panels and oblong panels the test confirms reasonably well the results of the best mathematical analyses. The test, however, showed much greater strength in the slab than the best analysis would indicate.

The report of the test has been completed and will be combined with a mathematical analysis of this type of slab to be published as a technologic paper.

Tests of Bond Resistance Between Concrete and Steel.

This investigation comprises tests made for the concrete ship section of the Emergency Fleet Corporation on (*a*) "pull-out" specimens in which steel bars were coated with various materials for protection against corrosion, and (*b*) on beams in which the uncoated reinforcing bars were spliced by lapping at the center of the span.

The "pull-out" tests consisted in measuring simultaneously the amount of load and the amount of slip during the pulling out of coated bars which were embedded axially in concrete cylinders having a diameter of 6 inches and a length of 12 inches. The tests indicate that, in general, the use of a coating to protect a bar against corrosion reduces greatly the bond resistance between the concrete and the steel.

The beam tests were made to determine how great a length of lap is required when tension reinforcement is spliced by lapping and without any other connection between the separate bars than that which is afforded by the bond between the concrete and the steel. The test results indicate that for a concrete of one part cement and two parts aggregate (having a strength of about 5,000 pounds per square inch), a lap of about 48 diameters of the bar is necessary. It follows that for leaner concretes a greater length of lap would be necessary. These figures assume that the yield point of the steel is reached at a stress of 40,000 pounds per square inch.

Pouring and Pressure Tests of Concrete.

These tests were made in connection with two minor investigations carried out at the Bureau of Standards for the concrete ship section of the Emergency Fleet Corporation. They were undertaken with the object of obtaining data useful for design under the special conditions involved in the construction of concrete ships.

The pouring specimen used was a slab 6 feet high by 6 feet wide and 4 inches thick, having a mass of reinforcement designed to reproduce conditions such as would occur in pouring the shell of a reinforced concrete ship. The reinforcing bars were placed so close together as to afford little room for passage and the form was further constricted by strips of wood nailed on the sides. The concrete was poured in three lifts, with the form standing in a vertical position. The test showed that under the adverse conditions represented by this test it was possible to obtain a smooth surface and a high strength of concrete.

For the measurement of pressure a specimen nearly 17 feet high was used. Pressure of the concrete against the forms was measured at various heights. The results indicated that the maximum pressure against the forms during the pouring of the concrete was equivalent to that of a liquid weighing 124 pounds per cubic foot. The maximum pressure was found to be that due to the head of concrete, which existed at the end of about 40 minutes after the beginning of pouring. After that time the pressure at the bottom of the form gradually decreased in spite of an increasing head of concrete.

Compressive Strength of Concrete in Flexure.

A paper on this subject has been prepared, in which use was made of hitherto unpublished test results obtained by (*a*) the U. S. Geological Survey in an extensive investigation of reinforced concrete in St. Louis from 1905 to 1908; (*b*) the Bureau of Standards, at Lehigh University, in connection with investigations for the concrete ship section of the Emergency Fleet Corporation; (*c*) Lafayette College, at Easton, Pa.

Previous to this paper few results have been published of tests in which failure of concrete beams was due to crushing of the concrete. The paper shows that with concrete of the quality ordinarily assumed to be furnished for construction purposes there is much greater strength in compression than in tension. The indications are that for the design of reinforced concrete beams the working stresses in compression might safely be made considerably higher than those used at present in standard practice, providing that a little greater uniformity in the strength of concrete can be secured than has been the case in the past.

Volume Changes in Mortars and Concretes.

Investigations carried on in this field during the past year have yielded a number of results of considerable value. With the Bureau's present equipment, refined methods of measurement are possible, and as a result, accurate measurements of volumetric changes that occur in mortars from the very time of making have been obtained. During the present year a number of practical problems have been dealt with, such as the determination of initial and total volume changes in mortars and other standard mixtures, hydration effects, effects of retempering, and influences of various types of bases.

Tests have shown that the usual rather severe volumetric changes that may occur in mortars suitable for stuccos during the period of setting may be entirely eliminated by proper control of moisture conditions during this period, so that the danger of having destructive cracks develop because of these initial volumetric movements will be largely or wholly avoided. The effect of retempering (that is, the remixing, or the continual mixing of a mortar for a considerable period before placing) was studied because of the question that exists as to whether retempering improves or impairs the quality of the mortar. Results indicate that retempering causes the occurrence of greater volumetric changes, so that in this respect at least it is not to be recommended. Experiments made with mortars cast in forms with various types of bases have given valuable information as to the influence of the condition of the base itself on volume change. It has been found possible with the use of an absorptive base to eliminate in standard mortars practically all of the usual shrinkage that occurs during the period of setting and to reduce by approximately one half the later volumetric changes. This information is of particular importance in stucco and plaster work for it suggests the necessity for control of "suction" if the volumetric change in the applied coat is to be reduced to a minimum.

As indicated above, the laboratory work has been confined largely to mortars and a report on this phase of the investigation will be prepared during the coming year. A month's field work has also

been included, partly in connection with the reinforced concrete investigations of the Section and partly in measurements on test slabs of the Coleman Dupont highway in Delaware. The latter were started in 1915 and will possibly be continued for another year before a report on the studies of these slabs will be prepared.

Fineness of Cement and Other Materials.

Under this heading are included investigational work in connection with the study of properties of very finely divided materials, the standardization of testing sieves, and the preparation of samples of cement of standard fineness.

Air Analyzer.—This apparatus was developed some years ago for determining the extreme fineness of cement and other pulverized materials in a region beyond the reach of mechanical sieves. Aside from minor improvements in the accessories no changes have been introduced in the form of this apparatus, nor in its manipulation. During the year mechanical analyses have been made with the analyzer and sieves on samples of cement, paint pigments, ground silica, ground feldspar, foundry and other sands, gravel screenings, clays, and metal powders. One investigation, carried out for the paper section of the Bureau, involving much time and labor, was a comparison of the mechanical analyses of twelve samples of English and American clays, to determine the relation of fineness to quality as paper fillers.

Standard Cement Sieves.—During the year fifty-six 200-mesh sieves were standardized. In the annual report for 1918 it was noted that it had become difficult to obtain 200-mesh sieves that would meet the standard specifications. During 1919 there was an improvement in the quality of the sieves submitted to the Bureau for standardization. On the whole this improvement has continued and sieves meeting the standard specifications may now be obtained from a number of manufacturers.

A comparative study has been made with the chemical division of the Bureau on the standard method of making fineness determinations (of cement) and the wet sieving process as used in determining the fineness of paint pigments. Owing to the fact that in the latter process 3-inch sieves are used in lieu of 8-inch sieves, and a 5-gram sample in lieu of 50-grams, the results obtained are not directly comparable, but the tests established the fact that the standard method for cement is of the same order of accuracy as the wet process, and simpler in that it does not involve the use of chemical equipment. The studies also established the need for correction factors for the 3-inch sieves, if used in the fineness determinations of materials of medium fineness, such as portland cement.

Some attention has been given also to measurements of particles passing various standard 200-mesh sieves in a search for a further check upon the quality of the sieves, but owing to the limited accuracy of these measurements, unless taken in large numbers, the method is not promising.

U. S. Standard Sieve Series.—Specifications for a new series of standard testing sieves have been developed in cooperation with the weights and measures division of the Bureau. In connection with the standardization of these sieves, the present specifications are based

only upon average measurements of openings and wire diameters, with certain tolerances upon these averages and upon the maximum openings. It is recognized, however, that appreciable differences in sieving values of sieves meeting these specifications will exist, particularly in the finer sieves, and data will be obtained as the new sieves come into general use as to the magnitude of these differences in sieving values, and the need of correction factors to be applied whenever results of the highest obtainable accuracy are required. At the present time all sieves finer than the No. 80 submitted for certification as to conformity with the new specification are being tested for sieving values with the standard cement samples, and plans are being considered whereby a more suitable material may be made available for this purpose.

Two manufacturers of wire cloth are now furnishing sieves according to the specifications for the U. S. standard sieve series, and a third manufactures a series of testing sieves of which the majority nominally conform to these specifications.

Standard Samples.—The Bureau prepares and keeps on hand for issue standard fineness samples of cement for checking up 200-mesh sieves. They are supplied in two degrees of fineness and are issued in sealed glass jars, each jar containing about 160 grams, enough for three 50-gram sieve tests. Each sample is accompanied by full directions for its use. A nominal price of 50 cents, sufficient only to cover the cost of preparation, is charged for each sample. With these samples 200-mesh sieves may be compared with the fundamental standards and correction factors obtained. These samples are also used by the Bureau in checking up its own sieves and in the standardization of 200-mesh sieves submitted for certification. On account of the exhaustion of the Bureau's old supply, it was necessary in the early part of the year (1920) to prepare new standard samples. The new samples are: 46f–80.5 per cent passing the 200-mesh sieve, and 47c–89 per cent passing the 200-mesh sieve.

Stucco.

Previous work in this investigation has been supplemented by field inspections to study climatic effects upon the durability of stuccos. Structures were examined in Georgia, Florida, Alabama, Louisiana, Tennessee, Kentucky, Ohio, Illinois, Wisconsin, Minnesota, and California. The data obtained indicate that durable and satisfactory stuccos can be produced in any section of the country, provided the work is in the hands of those who are familiar with the requirements of this class of construction and know the limitations of the materials entering into it. Stucco troubles may be attributed to two main causes, (1) cheapness of construction, which precludes the use of proper materials and methods, (2) lack of knowledge of fundamental requirements, in which both architects and plasterers are at fault.

Reliable information in regard to stucco construction is contained in the Recommended Practice for Portland Cement Stucco, published this year by the American Concrete Institute and based upon experimental work and field inspections conducted by the Bureau.

Concrete Tanks for Oil Storage.

An investigation of the suitability of concrete tanks for oil storage was undertaken for the Navy Department and the Shipping Board

in 1918. Because of the subsequent rapid introduction of this type of tank for oil storage in the industries, the investigation has been continued and probably will extend into the next two or three years.

The qualitative storage tests of 18 different oils, described in the last annual report, have now been under way for two years. None of the tanks have been affected by the mineral oils, and of the animal and vegetable oils only coconut and lard oil have shown visible disintegrating effects. In addition, the raw linseed and neats'-foot oil have attacked to some extent the test cylinders immersed in them.

The quantitative tests referred to in the annual report for 1919 have been supplemented by an extensive series of tests of 1:1½:3 concrete tanks, which are representative of the construction of oil tanks for industrial purposes. These tanks have been filled with mineral oils covering the entire range of fuel oils and the rates of seepage determined. After the rates of seepage became practically constant under low pressure, a tank which represents typical behavior for each oil is put under a pressure head of 35 feet and the rate of loss determined under these conditions. These tests will later be used as a basis for determining the relative merits of various recommended oil-proofing treatments.

As the test tanks used in the oil-storage investigations have proven very satisfactory for permeability tests, certain comparisons have been made on various concretes for water-tightness. It was found that 1:2:4 concretes gaged with 8, 9, and 10 per cent of mixing water were more permeable in the order named, although all these tanks were bone dry on the outside when tested with water under 35 feet head. Comparison of 1:2:4 concretes made with the centrifugal mixer and a mixer of the open-pot type showed permeabilities of the same order of magnitude.

The year's work included a three months' field survey of concrete tanks in use for storing fuel oils for industrial purposes, and in the oil fields for storing crude oils. Concrete tanks without special treatment are proving successful for the storage of oils as light as 40° Baumé, and in several cases oil-proofed tanks are apparently retaining gasoline with negligible losses. One of the chief advantages of concrete storage is the fact that the tanks are built below ground and thus avoid the wide temperature variations which are sources of trouble in steel tanks above ground. In concrete oil storage the fire hazard is minimized, and by designing the roofs of tanks for definite loads valuable space in the factory yard is made available for other purposes. The fundamental requirements in successful concrete tanks and reservoirs are careful attention to foundations and to concreting methods, which will insure the continuity and impermeability of the concrete itself.

Automatic Freezing and Thawing Apparatus.

This apparatus, designed for the purpose of making weathering tests on building stone, concrete, brick, and similar building materials, has been modified from the original form in order to give more uniform conditions throughout the test. In the present form the specimens are thawed in water, which also serves to control the degree of saturation. This form of the apparatus promises to give results which can be correlated with actual weathering in structures and reduce the time and labor of the test to such an extent that it will be

practical to make a large number of freezings under normal conditions of saturation.

Grading of Indiana Limestone.

The work undertaken for the purpose of establishing a more definite means of grading Indiana limestone has been completed, with the exception of weathering tests, which have been held up for the completion of the freezing apparatus. The results indicate much overlapping of physical properties from one grade to another, and from the present data it appears that a system of grading based on such properties as strength, absorption, specific gravity, etc., would not be more satisfactory than the present basis, viz, that of texture.

Freezing Tests of Sandstone.

Several samples of sandstone have been experimented with in the freezing test. Some of these have withstood 300 freezings without showing visible effects, while others were completely disintegrated by 100 or less. All samples showed a loss in strength due to freezing, and the percentage loss appeared to depend principally on the original strength of the material. In a general way a relation was indicated between the loss in compressive strength and the percentage of absorption of the materials, viz, those having the highest absorption suffered the greatest loss in freezing, but the relation was not so clearly marked as that between the original strength and the loss in freezing.

Laboratory Tests in Relation to Durability of Building Stones.

In order to compare the results obtained in the laboratory weathering tests with actual weathering numerous structures were examined which showed the effect of exposure for various periods of time. The materials studied included 8 varieties of limestone, 13 varieties of marble, 11 of sandstone, and 12 of granite. Several buildings, monuments, etc., were inspected which were over 100 years old. Only a few granites were found that showed appreciable decay, and some sandstones appeared to be almost as resistant, while most types other than the granites showed considerable disintegration after 50 years' exposure. With sandstone the actual weathering appears to compare very well with the results of frost-action tests made in the laboratory. With limestone the actual weathering seems to be a combination of frost action and chemical solution, which will require the modification of the present laboratory test to give comparable results. With marble the principal weathering agent seems to be that of chemical solution, but frost action is important at bedding planes and other places where water may readily penetrate the stone. The few cases of decay in granite make the study of the causes uncertain, but thin exfoliation of the surface seems to indicate that the chief element of destruction is that of temperature changes alone. Hence it appears that a large amount of experimentation will be necessary to establish a test that will give results on all types of stone to compare with actual weathering.

Discoloration Tests.

Tests are in progress to determine the cause of staining and efflorescence on the surface of limestone structures. Twelve limestone panels, each approximately 3 feet square, have been erected on

the roof of one of the Bureau's buildings, in which the stone was set with normal Portland cement, white Portland cement, slag cement, natural cement, and lime mortar. All of the panels have red-brick backing, and different processes of waterproofing have been used in a part of the panels. These panels were erected in September, 1919, and efflorescence soon appeared on the surface of all the panels, which increased in amount during the winter months. Early in the spring the greater portion of this disappeared, due to cleaning by heavy rains, and has not reappeared in prominent quantities. The very slight amount of staining which has occurred does not seem to bear any relation to the types of mortar used.

These exposure tests are supplemented by leaching tests in the laboratory which are designed to differentiate between the staining due to soluble salts in the stone itself and that due to mortars.

Durability of Cement Drain Tile and Concrete in Alkali Soils and Waters.

Field investigation was resumed in 1919 after three years suspension during the war. This investigation, started in 1913, includes the installation of 21 series or types of cement drain tile in working drains in eight localities where large quantities of alkali salts are found in the soil. These drains were installed at Garland, Wyo.; Fort Shaw, Mont.; Sunnyside, Wash.; Yuma, Ariz.; Roswell, N. Mex.; Montrose, Colo.; Grand Junction, Colo.; and Huntington, Utah. For purposes of comparison, drains were installed in the humid region where no alkali is found, at Crookston, Minn., and Columbia, Mo. Sufficient quantities of each type of tile are installed in each drain to permit extending the tests over a period of 20 years or more. In addition to drain tile large groups of concrete blocks were molded in 1915 and installed in alkaline sloughs at Garland, Wyo.; Fort Shaw, Mont.; Sunnyside, Wash.; Fallon, Nev.; Mesquite, N. Mex.; Montrose, Colo.; and Grand Junction, Colo., and Newell, S. Dak. A large lot of blocks 10 by 10 by 30 inches long were molded at Denver in the proportions $1:1\frac{1}{2}:3$ and $1:2\frac{1}{2}:5$, and some were shipped to each of the above places. At each place similar blocks of the same proportions were molded, using the materials in common use for concrete work in that locality. The wide variation in the cements and aggregates used, together with the different conditions to which they are exposed, permit valuable observations to be made as to the durability of various qualities of concretes, all results being tied together by observations of the Denver blocks under similar conditions.

While this investigation is by no means completed, the results of tests and observations to date permit several definite conclusions to be drawn and point out logical steps to be taken in extension of the investigation. During the spring of 1920 a field investigation was made of the conditions of various concrete structures in the prairie Provinces of Canada. Observations made on this trip strongly emphasize the conclusions already derived from investigations in the States and indicate that aside from the more severe weather conditions the alkali problem is identical with that in this country.

The following comments and conclusions seem to be justified by the results of the investigation, but will be subject to modification and enlargement as more data become available.

1. Sulphate waters as a type appear to more seriously affect concrete than chloride or carbonate waters.

2. Severity of action on concrete in sulphate waters appears to vary with concentration of soluble salts.

3. Under given conditions of concentration durability of concrete appears to vary directly with richness of mix and impermeability of mass. The latter property is partially dependent on the richness of mix and indications are that permeability alone is the best criterion of durability.

4. Even though certain qualities of concrete may be identified and specified, which will safely withstand any given degree of concentration, it will probably not be possible to discover what maximum concentrations may later be found or developed in any district. Experience has shown that analyses of water samples taken at the outlet or intermediate points in a drain give little indication of what concentration may be encountered a few feet away. In 1919 at one block installation subsoil water in the ground just outside the block site showed a concentration of 0.51 per cent soluble salts, the surface water a few feet distant surrounding the blocks had a concentration of 3.31 per cent and a small pond on the side opposite the location of the first sample had a concentration of 0.93 per cent. Similar conditions have been found in tile drains.

5. If concentrations are high even the best quality of concrete may be attacked. Where unusually high concentrations are found in advance of construction, every possible precaution as to thorough drainage should be employed so as to keep alkaline ground waters away from the structure.

6. Since all results indicate that the quality most needed for exposure to alkali waters is impermeability it seems that progress can best be made in the investigation by a series of laboratory tests to determine the variations in materials and methods of manipulation which affect this property. This work can be done most economically, quickly, and efficiently in the laboratory, to be later followed by duplication of the most promising concretes in the field. It is proposed to follow this plan in the continuance of this investigation.

Preliminary Examination of a Proposed Site for a Cement Plant.

In compliance with a request of the State officials of Mississippi, a representative of the Bureau visited Oklona, Miss., for the purpose of making a preliminary examination of the State's property at that place relative to its suitability as a location for a cement plant. The submitted report gave the results of general observations and a number of chemical analyses of the available raw materials with their application to the manufacture of Portland cement. Also, some general data were given on the cost of erecting and operating a cement plant, together with a brief discussion of the more important conditions upon which largely depends the degree of success attained in undertakings of this kind.

Measurement of the Consistency of Concrete Mixtures.

The "flow table," developed in the concrete laboratory in 1919 and described in the last annual report, has been used continuously in all concrete tests and investigations, and is now considered an indispensable part of the laboratory equipment. A paper by G. M.

Williams describing this apparatus in detail and its application to concrete testing was published in the Engineering News-Record of May 27, 1920. The flow table has been found applicable to the measurement of other properties of concrete than consistency or flowability, e. g., the measurement of the time of set of mortars and concretes can be determined by testing the molded mixtures at regular intervals after mixing; the harshness of a mix, or its tendency to segregate, can be compared with that of other mixtures containing different proportions of fine and coarse aggregates or additions of finely divided materials to improve working quality; from preliminary tests of concrete containing different proportions of given materials, in which the consistency is controlled, strength may be predicted for all combinations of ingredients. The utility of the flow table for controlling and measuring consistency has been demonstrated at a large cement brick plant in New York, where the type of machines and the methods of handling require control of this factor within narrow limits. Another practical application of the instrument was shown where an accelerator was being used in a concrete floor topping to shorten the time required for finishing. The time of set of the treated mortar was in this case found to be one-half that of the untreated.

Centrifugal Concrete Mixer.

A very extensive series of tests, extending over a period of several months, was made to compare the mixing action and the concrete produced in a new type of centrifugal mixer with that produced in an open-pot type widely used in commercial and laboratory work. The centrifugal mixer, of one-half yard capacity, consists essentially of a horizontal bowl which can be rotated about a vertical axis at 70 to 80 r. p. m. The contents of the bowl are thrown outward and upward by the centrifugal action, and are deflected back in streams to the center of bowl by four fixed deflectors attached to the stationary frame. To discharge the mixer one of the deflectors is slightly raised, permitting the contents to flow over the rim of the bowl into a hopper or chute.

The comparisons were first made on batches similar in all respects, but it was found that the severe grinding action in the centrifugal mixer reduced the fine aggregate to such an extent that decidedly stiffer consistencies were obtained from this machine. Hence later comparisons were made in which the same consistencies or flowabilities were maintained by additions of the required amounts of water. The results of the tests may be briefly summarized as follows:

1. The work done on the mass of concrete by the centrifugal mixer is greatly in excess of that done by the laboratory mixer. The velocity of flow in the former is such as to produce a ball mill action, the coarse aggregate grinding the fine to a remarkable extent even in a mixing period of two minutes. The increase of fine material thus produced is such as to require from 5 to 10 per cent more water to maintain the same degree of flowability as that in a similar mix in the laboratory mixer.

2. The results of the tests indicate that if similar batches of aggregate, cement, and water are mixed in the same proportions in the two types of mixers, the strength of the concrete produced by the centrifugal mixer is about 20 per cent higher, on the average, than that

mixed in the open-pot mixer. As explained in the preceding paragraph, however, this additional strength is attained at a sacrifice of flowability, which detracts from the apparent superiority of the centrifugal mixer in comparative tests. When similar batches were mixed in the two mixers with an adjustment of the water content to yield concretes of the same consistency or flowability, the strengths were found to be more nearly equal. The average of all comparisons on this basis indicate the concrete mixed in the centrifugal mixer to be approximately 7 per cent stronger than that from the open-pot mixer.

3. The excessive mixing action of the centrifugal mixer is an advantage in one important respect. Thorough mixing of a batch under normal conditions can be obtained in 15 to 30 seconds, and in general the strengths obtained from the 15-second mixes are as high as those of longer periods. It appears that the amount of mixing action per revolution of the bowl of the two mixers is nearly equivalent, and in this respect the output of the centrifugal of properly mixed concrete is much greater than that of the laboratory type.

Accelerators.

Preliminary work on "Cal" (calcium oxychloride) as an accelerator, described in the last annual report, has been supplemented by further work on mortars and concretes, in comparison with calcium chloride. The investigation as outlined has been completed, and the results are contained in a paper, "Effects of Cal as an Accelerator of the Hardening of Portland Cement Mixtures," which has been submitted for publication as a Technologic Paper. In brief, the effects of this material are approximately the same as those of calcium chloride—it tends to correct unsoundness and quick set in abnormal cement, it decreases the time of set of normal cements by approximately one-half, it hastens the early hardening of mortars and concretes, and has the advantage over calcium chloride in convenience of handling.

In view of the unusual claims made for a new proprietary waterproofing and hardening liquid placed on the market at a very high price and widely advertised during the past year, an extensive series of tests was made on mortars and concretes in which the effects of this material were determined. As preliminary chemical analysis indicated the liquid to be a solution of calcium chloride in water, the comparisons were made throughout with plain water and solutions of commercial calcium chloride of equivalent strength. Very complete chemical and physical tests indicated that the commercial chloride and the proprietary liquid were essentially the same both in composition and in their action on mortars and concretes.

Service Tests on Concrete Floors.

These tests have been in progress for almost two years, and have proven to be of considerable value in furnishing data concerning the relative value of the principal commercial compounds sold for this purpose as well as a few treatments that are not sold under trade names, and are hence more economical.

The treatments may be divided into three types, viz, chemical hardeners, surface coatings, and waxes. The first includes sodium

silicate solution, magnesium fluosilicate solution, aluminum sulphate solution, and zinc sulphate solution. The second class consists of hard drying paints and varnishes, and under the third class are two distinct wax treatments, one applied in solution and the other in a molten condition.

All chemical hardeners have given good results. Two of the treatments may be readily prepared and applied by inexperienced persons at small expense. These are sodium silicate and aluminum sulphate. The surface coatings are believed to be the most effective for entirely eliminating dust, and are desirable where delicate machinery exists, which would be damaged by very fine particles of grit. However, these are expensive and may have to be replaced under heavy traffic as often as once a year. The wax treatments have not proven very satisfactory in these tests. The one which is placed in a molten condition gave a good surface to a rather poor floor for a period of one year or more, but its cost is too great to justify its frequent renewal.

Effect of Storage on Cement.

The deterioration of cement which has been in storage for a long time or has been exposed to extreme weather conditions has been repeatedly brought to the Bureau's attention during the past year. During the war large stocks of cements were gathered for construction work at various camps, and due to delays some of these stocks were stored for long periods before being used. Tests of such cements in concretes indicated that the concrete-making qualities of the stored material had been so reduced that concretes having only 30 to 50 per cent of normal strength at 28 days resulted, although the material originally met the standard cement test requirements. Generally such cements in concretes will regain a portion of the lost strength at later periods, but experience on several jobs has indicated that this regain can not be depended upon, and such cement is particularly dangerous for use in cold weather work. Although meeting the laboratory specifications for setting time, concretes made with heated aggregates and protected for weeks from freezing have failed to harden properly with the result on one job that a large structure had to be removed and replaced. In connection with tests of old cements it has developed that the mortar tensile tests do not indicate properly the low cementing qualities of such cements when used in concrete and tested for compressive strength. The entire subject demands further investigation at the earliest opportunity.

Loss of Water in Molds.

Several series of tests have been made to determine how the compressive strength of concrete test specimens is affected by permitting mixing water to escape from 6 by 12 inch iron cylinder molds during the first few hours of hardening. The molds in use consist of 6-inch diameter black iron pipe split longitudinally with an element about three-sixteenths inch wide removed. By means of lug angles and bolts with winged nuts the slot may be closed previous to filling. Such a seam is not water-tight in all cases. This, as well as the unsealed base, permits small quantities of mixing water to escape, especially from the wetter consistencies. The results of the tests indi-

cate that loss of water under these conditions has no effect in increasing strength different from that produced by the natural settlement of similar mixtures in water-tight molds, and the consequent expulsion of water at the top.

Concreting Trouble in Cold Weather.

Inspection was made to determine the cause of vertical cracks appearing in the columns of a large concrete ice-storage house under construction in Philadelphia. The construction consisted of heavy concrete columns designed to support the steel roof trusses with the space between the columns filled in with heavy concrete curtain walls whose inside faces were flush with the inside faces of the columns. Cracks did not appear at the junction of wall and column as might be expected but were confined to the exterior faces and sides of the column. Tests of the materials used indicated that all were normal in quality and that the cracks were probably due to slight expansive movements in the vertical sheathing of the wood forms in contact with the concrete surfaces. Owing to the low temperatures at the time the work was under way, the rate of hardening of the concrete was naturally slow and slight expansion or swelling caused by absorption of water by the sheathing, probably aided by freezing of the sheathing, caused slight movements which were transferred to the concrete surfaces after the concrete had lost its plastic condition and before sufficient strength was developed to overcome the slight bond between the concrete and wood form.

Field Tests of Concrete.

Tests which have been made in the laboratory of concretes prepared on construction jobs in the field emphasize the need of a well-planned program of field tests on all important concrete work. It is customary in advance of work to make a few strength tests with the aggregates which are to be employed, especially if the engineer or contractor is unfamiliar with aggregates from that particular source, but very rarely are specimens of concrete later taken from the work for test. It is commonly assumed in design that a 1:2:4 proportion concrete will have a compressive strength of 2,000 pounds at 28 days, but our experience has been that more generally values of 1,200 to 1,400 pounds are obtained. Using the flowabilities which must be employed on most work it is often impossible even in the laboratory to attain 2,000 pounds with the specified proportions. Most engineers' and architects' ideas concerning the strengths of concretes have been obtained from the results of laboratory tests made without consideration of the controlling factors which are met with in the field. More attention to the results which are actually being obtained on the work may in many cases cause serious alarm, but the outcome should be an improvement in the quality of field concrete and a better understanding on the part of all concerned of the difficulties which must be met and overcome "on the job."

Wet and Dry Aggregates.

On most concreting jobs sand and gravel are proportioned by volume. While the bulking effect on the reduction in weight of sand per cubic foot due to the addition of water up to certain limits is

well understood, the actual effect on the quantity and cost of concrete produced, caused by variation in the amount of moisture in the sand is not so well known to engineers and contractors. Using the same volume proportions, dry sand results in a greater bulk of wet concrete than does wet sand, hence more cement will be used per cubic yard of concrete when wet sand is employed. This condition is brought about automatically and can be controlled and modified only by the use of a greater bulk of sand when wet sand is used. Data obtained on this subject indicate that the excess quantity of cement involved by using wet sand instead of dry may amount to more than 10 per cent, and the additional strength may be considerably greater than this. The matter is interesting, not only from its economic importance, but also from the fact that it suggests the advisability of determining more fully the effects of wet aggregates on compressive strength, facility of mixing, etc.

Oversanded Mixes.

Some work has been done with "oversanded" concrete mixtures. By "oversanding" is meant the use of a larger proportion of sand to coarse aggregate than is usually specified. Specifications, especially in structural work, usually call for a 1:1½:3, 1:2:4 to 1:3:6 proportion in which the sand volume is 50 per cent of that of the coarse aggregate. In "oversanded" mixes the ratio of sand to coarse aggregate may be increased to 0.6, 0.75 or even 1, reducing the volume of coarse proportionally so that the volumes of sand and gravel remain constant. The advantage of "oversanded" over the usual mixtures were as follows: (1) "Oversanding" results in an easy working, more plastic mixture which shows no tendency to segregate when using wet consistencies. Owing to the relatively large volume of mortar, the flowability of the mortar in an "oversanded" mix is less than in a normally sanded mix, although the flowabilities of the two concretes are equal. (2) Slightly less cement is used per cubic yard of wet concrete. (3) Compressive strengths will be higher for the "oversanded" mixtures, in case the sand is not too fine. Tests with Potomac River sand indicate that "oversanding" may be beneficial up to 1:3:3 in place of the usual 1:2:4 for regular run gradation. With other lots of sand the desirable limit of oversanding was found to be 1:2½:3½ and with some "oversanding" resulted in slight strength decreases.

New Experimental Cement Plant.

With the transfer of the investigations dealing with the production of Portland cement from Pittsburgh to Washington, it was thought advisable to enlarge the experimental cement plant. Consequently larger crushing and grinding machinery and a new rotary kiln 3 feet in diameter and 30 feet long were installed. One of the first investigations outlined for the equipment is the burning of a number of domestic magnesites to plastic magnesia. This will be followed by the burning of some Portland cement mixtures to which various fluxes have been added to reduce the clinkering temperature.

Magnesite Deposits.

During the year a representative of the Bureau visited several of the magnesite mines in California and Washington where the ore is

or may be obtained principally for the plastic trade—especially for flooring and stucco. The reports somewhat current in the East to the effect that the amount and the quality of the ore available in these localities is small and poor are without any basis of truth. On the other hand the quality of the amorphous ore is excellent, and while the crystalline has too much color for white products, yet it is eminently satisfactory for the greater number of uses to which plastic calcined ore is put. The quantity of both kinds is tremendous and should not give the user any cause of uneasiness as to shortage for years to come.

Sorel Cement.

Better progress has been made in the investigations dealing with Sorel cement (magnesia-oxychloride) during the year than was previously the case. This has been due to acquiring a knowledge of some of the effects of the unknown variables, which has rendered it possible to lay out a more advantageous program for attacking the problem. Thus it was found desirable to confine the work to magnesites burned in the laboratory to determine both the effect of time and temperature of burning and size of material entering the kiln. Thus far the results obtained with material burned in an electrically heated rotary kiln show that all three of these variables very decidedly change the properties of the resulting magnesia both as to strength and constancy of volume. With the completion of a series of burns in this kiln it is proposed to burn a number of domestic magnesites under certain conditions in the 3-foot by 30-foot rotary kiln of the Bureau. Enough calcined ore will be obtained to permit of making not only the usual laboratory specimens but also several service panels of stucco and flooring.

Miscellaneous Tests and Investigations.

The Bureau has cooperated throughout the year with the Government engineers in charge of the construction of Key Bridge between Georgetown, D. C., and Rosslyn, Va., in numerous tests of cement, aggregates, and concrete taken from the work.

At the request of the office of Public Buildings and Grounds an inspection was made in May of the Lincoln Memorial and a report rendered on the condition of the marble in the structure.

An extensive series of tests on a commercial Portland cement of high fineness was carried out, supplementing the preliminary work described in the last annual report. The results confirmed previous data in that very large increases in strength were obtained in concretes as compared with normally ground cement. In connection with these tests it is interesting to note that none of the accelerators of the calcium chloride type are as effective in producing early hardening of concrete as the additional fineness (approximately 12 per cent in this case) of the cement itself. Moreover, the advantage in strength from the finer cement is maintained indefinitely, whereas the effect of the accelerators is generally lost after the 28-day period.

Tests of blast furnace slag as an aggregate for concrete, made at different times during the past few years, have been compiled. A study of the results indicate that so far as the material tested is concerned slag produces a concrete which is the equal of gravel concrete.

There were no signs of disintegration from any cause up to one year. Slag screenings, because of their lack of fine material, do not produce easily workable concrete when used as fine aggregate. Addition of fine sand or other fine inert material tends to improve this quality.

Paper molds have been furnished by the Bureau in a number of instances to facilitate the taking of samples of concrete from various Government projects. Field samples of concrete, aggregating some hundreds of test specimens, have been submitted by and tested for the following agencies: Chief of Transportation, War Department, in connection with construction of concrete vessels; public works officer, Philadelphia Navy Yard, in connection with construction of the new dry dock at League Island; contractors for the Quartermaster Terminal, Philadelphia; board of water commissioners, Hartford, Conn.; engineers in charge of Key Bridge, Washington, D. C., as above reported.

The Washington laboratory tested 296 samples of miscellaneous materials submitted in connection with Government work or investigations including aggregates of all kinds, building stones, alkali soils and waters, powders of various kinds for mechanical analysis, waterproofing compounds, drain tile, stucco materials, bricks, and concrete products.

The service of the San Francisco branch laboratory is worthy of particular mention in that aside from its cement inspection it handled 311 samples of miscellaneous materials. A great deal of work was done on bituminous coatings for concrete ships, and analyses were made of paints, oil, varnishes, clays, lubricants, metals, waterproofing compounds, and engine cylinder deposits. Departments and bureaus served by this branch included the Navy, Post Office, Shipping Board, Public Roads, Forest Service, Army Air Service, Lighthouses, and Reclamation.

Aside from cement inspection service the work of the Denver laboratory has consisted mainly in tests and investigations of concrete, concrete aggregates, and structural materials, largely for the Reclamation Service.

Testing of Cement for Government Purposes.

Shipments of certified cement for Government projects showed a marked decrease over the preceding year. However, with the completion or suspension of many war-time enterprises, it was noticeable that there was an increase in the demands from work of a more normal nature—dams and river development, irrigation, bridges, and District of Columbia work. Total shipments were approximately 1,200,000 barrels. Their monthly distribution is shown in the following table, which also affords comparison with the years 1916–17 and 1918–19. The former represents work before the unusually large demands of war activity, and the latter was the busiest year of the service. It is believed that shipments during the recent months would have been much larger had there not been such serious car shortage. If Panama Canal shipments are excluded from the totals, the increase of the past year over prewar requirements is marked.

Month.	Shipments of tested cement in barrels.		
	1916–17	1918–19	1919–20
July	36,568	1,121,960	144,421
August	14,941	1,053,167	168,141
September	58,765	1,053,998	138,164
October	32,150	948,937	133,462
November	27,388	719,711	118,648
December	16,012	247,137	80,939
January	29,063	186,806	79,894
February	43,744	182,265	66,285
March	54,525	311,210	70,835
April	48,718	280,229	79,590
May	64,325	255,646	53,798
June	76,646	227,857	56,605
Total	502,845	6,588,923	1,190,782
Excluding Panama Canal	207,125	6,403,923	1,044,032
Rejections	72,000	742,000	125,919

Inspection was made at 64 mills in the following 19 States: California, Colorado, Georgia, Illinois, Indiana, Kentucky, Maryland, Missouri, Montana, New Jersey, New York, Ohio, Pennsylvania, Tennessee, Texas, Utah, Virginia, West Virginia, and Washington.

Naturally the cost per barrel of this inspection was not as low as in the preceding year. This was due partly to the fact that changes in the inspection force could not keep pace with decreasing shipments, partly to the fact that unit costs are necessarily somewhat higher with a smaller volume of work. On the other hand the value of the work is not indicated alone by costs per barrel. The amount of cooperation and investigational work contributed in connection with the service is considerable, and not infrequently retests and special tests are made for the information of the purchasing department.

It is again to be earnestly recommended that the inspection and testing of cement be provided for by adequate appropriations. Estimates obtained from the Government departments during the latter part of the year indicate that approximately 2,000,000 barrels of cement will be required during the year ending June 30, 1921. All the funds available for both testing and investigational work in cement will not provide for this amount of inspection, and in the endeavor to provide for as much of this work as possible the continuing investigations will have to be in part set aside entirely and in part seriously curtailed.

Changes in the Branch Laboratories.

As planned in the preceding year, the San Diego branch laboratory was closed July 31, 1919, and the territory which it served was taken over by the San Francisco branch. Additional funds provided by the deficiency act and made available in November, 1919, enabled the San Francisco and Denver laboratories to be supplied with greatly needed equipment. Universal testing machines of 100,000 pounds capacity were installed at both points, together with improved equipment for testing concrete and concrete materials. Additional space was provided by the Treasury Department for the enlarged facilities at San Francisco.

Conference on Cement Specifications.

An important conference was held at the Bureau on May 10, 1920, between representatives of the American Society for Testing Materials and the Government departmental cement committee. Ever since the organization of the Joint Conference on Uniform Methods of Tests and Standard Specifications for Cement in 1912 the fineness requirement has been in dispute. The joint conference was unable to come to a final agreement on this matter, and consequently on January 1, 1917, the present specification was adopted, but with a reservation on the part of the Government committee that a higher fineness requirement would go into effect the following year. In the war emergency this requirement was deferred, but the Government committee eventually decided that the increase should be effective January 1, 1921. At the conference of May 10, however, an agreement was reached whereby the fineness requirement in the specification should be a maximum residue of 22 per cent on the No. 200 sieve, without tolerance in the fineness determination, effective January 1, 1921. This agreement therefore stands as the final achievement of many years' work on the part of Government engineers and representatives of the engineering societies to bring about uniform specifications for Portland Cement throughout the country.

Foreign Cement Specifications.

The war interrupted the collation of foreign Portland cement specifications. This work has now been resumed, and an effort is being made to obtain the latest specifications. Already many replies have been received from the consular agents in the various countries.

Publications Relating to Cement and Concrete.

The publications by the staff of the cement section include the following, which have appeared during the year:

Structural Laboratory Investigations in Reinforced Concrete Made by Concrete Ship Section, Emergency Fleet Corporation. (W. A. Slater.) Proceedings American Concrete Institute, Volume XV, page 24, 1919.

Tests of Concrete Tanks for Oil Storage. (J. C. Pearson and G. A. Smith.) Proceedings American Concrete Institute. Volume XV, page 186, 1919.

Cements Producing Quick Hardening Concrete. (P. H. Bates.) Proceedings American Society for Testing Materials. Volume XV, page 425, 1919.

New Developments in Surface Treated Concrete and Stucco. (J. C. Pearson and J. J. Earley.) Proceedings American Concrete Institute, Volume XVI, page 70, 1920.

Compressive Strength of Concrete in Flexure. (W. A. Slater and R. R. Zipprodt.) Proceedings American Concrete Institute, Volume XVI, page 120, 1920.

Tests of Plain and Reinforced Gypsum Beams. (W. A. Slater and G. P. Anthes.) Journel Western Society of Engineers, September, 1919.

Specifications for the United States Standard Sieve Series. (J. C. Pearson.) Proceedings American Concrete Institute. Volume XVI. page 70, 1920. Reprints of this paper are available for distribution to those interested, and copies may be obtained, until the supply is exhausted, on application to the Bureau.

Tests of Two Recent Theories for Proportioning Concrete. (G. M. Williams and Watson Davis.) Engineering News-Record, June 12, 1919. Subsequent discussions and contributions on this subject were published in Engineering News-Record, August 14, 1919, and April 22, 1920; Canadian Engineer, January 1 and 15, 1920.

How Can Laboratory Tests of Concrete Materials Be Made of Greater Value to the Field Engineer and Contractor. (G. M. Williams.) Engineering and Contracting, February 25, 1920; Concrete, April, 1920; Canadian Engineer, January 29, 1920.

Flowability of Concrete and Its Measurement by Means of the Flow Table. (G. M. Williams.) Engineering News-Record, May 27, 1920; Concrete, June, 1920; Engineering and Contracting, June 2, 1920; Canadian Engineer, June 10, 1920; Concrete Products, June, 1920.

The following are in course of preparation or in press:

Tests of Bond Resistance Between Concrete and Steel. (W. A. Slater, F. E. Richart, and G. G. Scofield.)

Pouring and Pressure Tests of Concrete. (W. A. Slater and A. T. Goldbeck.)

The Effect of Repeated Reversals of Stress on Double-Reinforced Concrete Beams. (W. A. Slater, G. A. Smith, and H. P. Mueller.)

An Investigation of the Causes of Cracking in a Concrete Barge. (W. A. Slater and G. G. Scofield.)

Test of a Concrete and Hollow Tile Floor Reinforced in Two Directions. (W. A. Slater, A. Hagner, and G. P. Anthes.)

Some Determinations of the Stress Deformation Relations for Concretes Under Repeated and Continuous Loadings. (G. M. Williams.)

LEATHER.

This work is concerned with the investigation and testing of leather and leather goods to determine the physical and chemical properties and relative durability of different kinds of leather upon which to base standards of quality.

Sole Leather.

Service tests to determine the comparative durability of chrome tanned and oak tanned sole leather have been completed. The chrome leather used was heavily filled with greases and was of the same type as is furnished to the shoe trade. The oak leather was tanned by the long-time process with vegetable tanning materials and represented a high quality commercial leather. Results of 28 tests showed that the chrome leather outwore the oak by approximately 23 per cent per unit thickness.

The following tests are nearing completion and the results will be available within a short time:

1. Comparative durability of hemlock leather filled with glucose and salts, and hemlock leather to which these materials were not added.
2. Comparative durability of hemlock leather filled with glucose and salts, and oak sole leathers to which only a small amount of glucose and salts had been added.
3. Comparative durability of hemlock leather not filled with glucose and salts, and oak sole leather to which only a small amount of glucose and salts had been added.
4. Comparative durability of waterproofed and nonwaterproofed oak sole leather.
5. Comparative durability of light and heavy rolled oak sole leather.

An investigation is in progress to determine the durability of leather tanned and filled with vegetable tanning material, as compared with leather tanned with vegetable materials and filled with sulphite cellulose extract. Five hides were prepared by each of three tanners for this work. One side of each hide was prepared with the vegetable tanning materials, while the other side of each hide was prepared by using sulphite cellulose extract for filling.

Leather is being prepared to determine the comparative wear of chrome and oak-tanned leather made from the same hide.

Harness Leather.

Tests have been completed showing the effects of the amount of stuffing content and the degree of tannage on the physical properties of russet harness leather. The results also show the variation over the hide of the tensile strength per inch of width and per square inch, buckle strength, percentage elongation, thickness, and the stuffing content.

Upper Leather.

Animal and Fish.—A study is being made of the merits of shark and porpoise leathers as compared with calf and side leathers for use in shoe uppers. The laboratory work will consist of comparative strength, elongation, tearing, moisture penetration, and microscopic tests of the two kinds of leathers.

Several shoe manufacturers are cooperating with the Bureau to the extent of furnishing shoes with which actual service tests will be made to compare the durability of these two leathers. One shoe of each pair will have a fish leather upper and the other shoe will have the calf or side leather upper.

Effects of Disinfectant.—Tests were made to determine the effects of disinfectants used by the War Department upon the upper leather and linings of Army shoes. Physical tests made on the treated and untreated materials showed no deterioration.

Organ and Piano Leathers.

In cooperation with the Bureau of Fisheries an investigation of leathers used in the manufacture of organs and player pianos has been undertaken with a view to ascertaining the suitability of animal and fish intestines for this purpose. A preliminary report has been issued describing the uses of the leather and the kinds of leather employed by numerous manufacturers. Difficulty is experienced at present chiefly with the sheep and lamb skin skivers used for diaphragms in the action.

Information thus far obtained shows that there is in general no leather which has been adopted as standard by all manufacturers for any particular purpose. An effort will be made to develop such standardization.

Microscopic.

An investigation of the structure of tanned leather is being made by the use of photomicrographs in order to provide means of identifying the various tanned skins.

Several methods of preparing leather specimens for microscopical examination have been studied and photomicrographs of various leathers have been prepared showing the fiber bundles, cross sections, and both the grain and flesh surfaces.

Special Tests.

Standard Army Shoes.—An investigation was made at the request of the War Department of the sutability of a proposed Army shoe for adoption as standard for all purposes. A favorable report was made by the Bureau as a result of service tests conducted at Camp Sherman and the shoes have been adopted as standard by the United States Army.

Visor Edgings.—A comparative test was made of sheepskin skivers and artificial leather for use as visor edgings on United States Army officers' caps. The artificial leather showed a greater strength than the real leather on account of the fabric backing. However, an inspection of the two materials in service showed that the coating of the artificial leather cracked and peeled off after a short time, and that the real leather remained in good condition. It was recommended that artificial leather be not used for this purpose.

Shoe Soles.

At the request of a manufacturers' association, a study was made of the merits of a special type of composition sole which had a veneered wood backing, as compared with leather. As a result of the Bureau's investigation, including actual service, pliability, flexibility, and conductivity tests, certain changes have been made in the details of design and further tests are now being made to determine the value of the new type of construction.

Routine Tests.

As usual a part of the time during the year was devoted to routine work in the way of physical tests and chemical analyses for the various Government departments and for manufacturers. The materials tested included sole leather, harness leather, strap leather, bridle leather, leather belting, fish leather, rawhide, calfskins, lace leather, baseball covers, welting leather, and artificial leather.

Specifications.

Specifications for black and russet strap leather were developed for the Panama Canal, and a specification for leather to be used in brief cases was developed for the General Supply Committee.

Publications.

The following publications were issued during the year:

Technologic Paper No. 138, "The Effects of Glucose and Salts on the Wearing Quality of Sole Leather."

Technologic Paper No. 147, "An Apparatus for Measuring the Relative Wear of Sole Leather and the Results Obtained with Leather From Different Parts of a Hide."

Technologic Paper No. 153, "Area Measurement of Leather."

Technologic Paper No. 160, "Effects of Oils, Greases, and Degree of Tannage of the Physical Properties of Russet Harness Leather."

Miscellaneous.

Artificial Leathers.—An investigation of the properties of artificial leather and the development of tests and testing apparatus are in progress with the idea in view of securing a suitable specification for this material. The Coated Textile Manufacturers' Association is cooperating in this work.

Pyroxylin Plastics.—The Bureau was requested to investigate the properties of pyroxylin plastics with the view of securing important information.

Samples were submitted by three representative American manufacturers. The physical properties are being investigated under different conditions of temperature and humidity. These data, to-

gether with information regarding the electrical, chemical, hydroscopic, optical, and thermal properties, will be published.

RUBBER.

This work is made up of the investigation and testing of rubber and rubber goods to determine their physical and chemical properties and to develop specifications, the manufacture of special rubber articles for use in the Bureau's laboratories and the development of methods of testing and design of new testing equipment.

Specifications for Automobile Tires and Inner Tubes.

All purchases by the War Department, Panama Canal, and other Government offices of solid and pneumatic tires and inner tubes are made on the basis of tests and analyses conducted at the Bureau. The Navy Department has likewise adopted specifications for pneumatic tires prepared in cooperation with the Bureau.

Power Loss in Tires.

Owing to an unavoidable delay in the delivery of dynamometer equipment no progress was made in the investigation of power losses in tires. The apparatus which is now available will be used in a series of tests to be made in cooperation with the Motor Transport Corps and the Society of Automotive Engineers. A study will be made of different types of tires and of tire fillers under definite conditions of speed, load on tire, and power transmitted. The results of this research will be of particular interest to tire manufacturers in view of the necessity for reducing to a minimum the energy dissipated in tires, which often causes a rise of temperature sufficient to produce serious injury.

The International Standardization of Tire Sizes.

The Bureau has cooperated with the American Metric Association in recommending and promoting an international standardization of tire sizes. The importance of such standardization was brought out very clearly during the war, when it was found necessary to change the wheels on some of our motor cars in order to permit the use of tires manufactured abroad.

Hospital Rubber Supplies.

The Bureau was called upon during the war to conduct numerous tests and analyses of hospital rubber supplies for the War Department. As a result of this work and at the request of the Field Medical Supply Depot of the Army, specifications have been prepared for stoppers, tubing, hot-water bottles, ring cushions, sheeting, and surgeons' gloves.

Rubber Used in Connection with Airplane Equipment.

The Bureau has cooperated with the Air Service of the War Department in the development of specifications for leak-proof gasoline tanks and rubber shock absorbers. and in the production of a satisfactory rubberized silk fabric for diaphragms used in connection with autographic instruments. Diaphragms of thin and very

flexible rubber have been made for use in connection with specially designed instruments.

Fire Hose.

Work of testing fire hose for Government departments has been continued. For a number of years all hose used by the local fire department has been purchased on the basis of tests and analyses made at the Bureau. The specifications formerly used are now being revised by the Bureau.

Miscellaneous Rubber Goods.

Under this heading are included a large variety of articles, such as hose of various kinds, belting, valves, packings, rubber-covered wire, shock absorbers for airplanes, jar rings, rubber bands, etc. A total of 772 samples were tested during the year.

Rubber Jar Rings for Canning.

The Bureau has continued its cooperation with the Department of Agriculture in the testing of jar rings. A specification developed by request of the States Relation Service has served a useful purpose, having been published by the Department of Agriculture and recommended for use by the public. The simple and practical tests called for in this specification have proved to be an effective means whereby the user may detect inferior quality in jar rings.

Rubber Analysis.

An important part of the Bureau's analytical work consists in the determination of the amount of rubber and ingredients that are used in rubber goods purchased by the various Government departments. The long list of ingredients mixed with rubber is constantly being enlarged. The properties of some of these ingredients are such that the usual methods of analysis give incorrect results. Thus the existing methods must be frequently added to or revised.

The use of glue, cellulose, and free carbon made it necessary to develop methods of analysis by which these ingredients could be measured quantitatively. These problems have been completed after more than a year of experimental work. Papers on the detection and determination of glue, and on the determination of cellulose and free carbon have been published. A paper on the use of mixtures of acetone and chloroform and of acetone and carbon bisulphide for the extraction of rubber goods has also been published.

A large amount of antimony sulphide is used as a red pigment and sulphur carrier in rubber goods. A satisfactory procedure for the determination of antimony which has recently been worked out will be prepared for publication in the near future.

The mineral fillers in vulcanized rubber are usually determined by ignition. This involves the loss of some constituents and changes in the composition of others. By use of a suitable organic solvent it is possible to remove the rubber and to leave behind all the mineral matter practically unchanged in composition. For more than a year this problem has been studied at intervals. One excellent solvent, because of its slight action upon certain constituents, had to be discarded. However another solvent has been found which seems to be

all that could be desired. Additional work will be done to determine its value definitely before the method is given publicity.

The method for the determination of sulphur was so modified as to lessen the time required. Indeed, the Bureau's general analytical procedure has been modified in many minor details so as to save time without loss of accuracy.

Miscellaneous Materials.

The testing of miscellaneous materials has become largely a matter of routine according to methods developed during the past 10 years in testing Government supplies. As typical examples of such materials may be mentioned asbestos gaskets, canvas belting, linoleum, flax shot lines used by the Coast Guard, window cord, hack saw blades, shoe laces, etc. Special equipment has been developed for testing some of these materials and in such cases similar tests are made for manufacturers upon request.

TEXTILES.

The activities of this section are quite varied and include the investigation and testing of textiles to determine their physical, chemical, microscopic, and aesthetic properties, the development of new materials, preparation of specifications, investigation of manufacturing processes, and aid in the establishment of a scientific basis for textile testing.

Definition.

Textiles is rather a broad term and somewhat hard to define, but in general it may be considered to refer to such manufactured articles as fabrics, hosiery, and knit goods, felt goods, cordage, twine, laces, braids, and embroideries, which are made from a number of different raw materials, including cotton, wool, silk, flax, hemp, jute, etc. On account of the great diversity in the uses to which these materials themselves are put, they are somewhat difficult to classify. Unfortunately there is room for a great many misunderstandings under the present unsatisfactory methods of classifying textiles and the materials from which they are made, and it is largely for this reason that much of the work now under way at the Bureau has been taken up. A close cooperation between the textile manufacturer, the selling agencies, the public, and the Bureau is necessary in order to make this investigation a success. It is believed that the Bureau's position as an unbiased third party is a strong one, and is becoming recognized as such by both the makers and users of textiles.

General Facilities.

Owing to the improved facilities for research and test work, made available through the removal of the textile section to its new quarters in the Industrial Building, the Bureau has been able to occupy a more important position than ever before in relation to the textile industries of the country. Its cooperation with manufacturers of this class of goods will undoubtedly be greater than ever before.

The section may be considered as divided into seven groups for routine and research problems, namely:

1. For cotton manufacturing problems.

2. For wool manufacturing problems.
3. For felt manufacturing problems.
4. For the physical testing of textiles.
5. For the chemical testing of textiles.
6. For the microscopical and photomicrographical analysis of textile materials.
7. For the compilation of statistics and reference data.

In almost every textile problem presented to the Bureau for solution all the above facilities are employed to a greater or lesser extent. It is hoped that during the coming fiscal year progress along all the above lines will be sufficient to warrant issuing a series of publications dealing with textile testing.

Microscopy of Textiles.

Microscopic and photomicrographic methods are becoming of greater importance and are being more generally employed in the study of various problems arising in the manufacture and analysis of textile fabrics. This section has been able to make a more thorough study and analysis of the properties of balloon and airplane fabrics by means of photomicrographs of these materials than could otherwise have been done.

In the study of textile fibers and the analysis of fabrics for fiber composition the microscope is indispensable, and is becoming generally so regarded. In order to promote the intelligent and systematic use of the microscope in this field this section is preparing a series of photomicrographs of textile fibers which are intended to show as clearly and distinctly as possible their physical characteristics, such as relative lengths and diameters, markings, thickness and regularity of walls, shape of ends, etc. For this purpose, of course, the individual, and not a bundle of fibers, is used. It is also thought that considerable information regarding the standard grades of some of the fibers, such as wool, may be disseminated in this way.

Plans have been made for this work and a few of the photomicrographs have already been made. It is the intention of the Bureau to have this work completed by the end of the fiscal year 1920–21.

Nomenclature and Definitions of Textiles.

An outline has been prepared for extensive work leading to the standardization of the nomenclature of textiles and definitions of yarns and fabrics, pointing out the different characteristics and limits of acceptability. The great need of this work is demonstrated by the lack of information, which may be secured by the purchaser of even staple fabrics concerning differences between various kinds of material.

For specialized fabrics, the practice of various manufacturers of substituting materials and names has caused considerable confusion, and textiles that have practically nothing in common are very often sold under the same name. The work can not be handled wholly by the Bureau, but will call for the assistance of the manufacturers, the converter, selling agents of textiles, and the retailer, as well as associations interested in the study of home economics. A circular will be published, which will be enlarged periodically, dealing with this much needed work.

Problems of Wool Manufacturing.

At the request of the president of the National Association of Wool Manufacturers a conference was held at this Bureau to discuss the possibility of conducting a number of industrial research problems on wool manufacturing and performance of the various wool fibers, yarns, and fabrics. One of the most important problems submitted was that of the standardization of dyestuffs from a chemical point of view, going a step further than the work now being carried on at the Bureau of Chemistry, Department of Agriculture, with specific reference to the existing cooperation of this Bureau on color standardization as confined to colorimetry. It is possible in this way to classify dyestuffs which are capable of a definite performance and which are now sold under a multitude of names, varying with the manufacturers.

Through laboratory and service tests, which will aid in the solution of problems relating to manufacturing methods and the substances used, interesting results will be secured which it is hoped will point out the superior methods and ingredients.

Another very important problem submitted was the question of the effect on the warmth and wearing qualities of garments, of the introduction of blends of shoddy of different grades and also of cotton with virgin wool. Results already obtained from abrasion tests and measurements of tensile properties can be utilized to good advantage in these problems. Although the work has been only outlined in this year's report, actual progress and possibly the completion will be accomplished in the present fiscal year.

Aircraft Fabrics.

Both the training and operations group of the Balloon and Airship Division, War Department, and the Bureau of Construction and Repair, Navy Department, have decided to continue part of their large program of research on aircraft fabrics as originally outlined. The textile section has therefore extended its cooperation in a further endeavor to solve some very important problems. This work was started some few years ago, but has never been completed, although many things have been accomplished and important facts ascertained. With the new equipment, which was originally procured for this purpose, already installed, experiments will be greatly expedited. In the new experimental cotton mill it is possible to make airplane and balloon fabrics of various constructions and characteristics, depending on the required performance. These can be given the prescribed physical tests in our new constant temperature and humidity room.

Balloon Fabrics.

The balloon fabric committee of the Bureau of Standards, organized in 1917 to cooperate with the Army and Navy Air Services, has drawn up a schedule of proposed research on balloon fabrics, which has been followed in modified form during the succeeding years. The particular problem undertaken this year was the effect on the permeability of a variation in the thread count and the finish of the cloth used in making the fabrics.

Experimental cloths with a lower thread count than is at present required were made by the Pierce Manufacturing Co. and rubberized

by the Goodyear Tire & Rubber Co. under the direction of this Bureau, the Navy Department furnishing the necessary funds.

The weathering tests are not as yet complete, but from the data now on hand it is thought that further work along the same general lines will be recommended, as a successful solution of the problem will insure a fabric which can be produced in large quantities and at a much lower cost than the fabrics now in use.

World Cotton Conference.

A representative of the section attended the World Cotton Conference held in New Orleans and a meeting of the committee on research reports and statistics. The committee has been directed to consider and report upon a possible international system of reports and statistics covering all phases of the growing, marketing, and manufacture of cotton, as well as the need for and possibility of research work in the textile industries. It also recommends cooperative research in methods of testing fibers, yarns, and fabrics with the object of securing, as far as possible, standard international methods, and urges a uniform system of expressing results. In accordance with the above program this section is planning to be of the greatest possible assistance in the work outlined and to act as a clearing house for all information on possible solutions of research problems concerning the manufacture of fabrics and commodities.

Waste-Silk Fabrics.

In order to assist the Salvage Board of the Ordnance Department in disposing of a large quantity of spun waste silk, this section manufactured a small yardage of fabrics of special construction, having a spun waste-silk warp and a woolen filling. The fabrics were finished for show samples having a width of 28 inches. Complete anaylsis and testing brought forth indications of a superior fabric in regard to appearance, feel, and wearing qualities for the weight per square yard. This was the first investigation of this nature carried on in the new laboratories, and serves to illustrate the probable future usefulness of the installation.

Abrasion of Suitings.

Following the successful building of an apparatus for abrading textiles, a request from a private investigator to determine the resistance to abrasion of several samples of suiting, treated with a solution added to increase wearing qualities, was accepted. Requests of this nature serve to indicate the trend of thought in the textile industry along the lines of more complete and better knowledge of the uses and performances of textile materials. Two widely different types of fabrics were submitted to study the variation of the penetration of the solution into the interstices, and to determine the effect of the solution as a fiber coating for increasing the wear resisting properties.

The results expressed in per cent decrease in tensile strength showed that the solution did increase the strength of the untreated fabric, and the cause of this can be logically traced to the fact that the solution increases the bond between the fibers, thus increasing the fabric and yarn assistance. However, this does not necessarily prove or warrant a statement to the effect that the life was materially in-

creased, because of the wide deviations in results of tests on the treated fabrics.

The abrasion machine itself is not a finished product, and work on new designs, together with chemical research on the subject, is now underway. Results show the need of more detailed measurements, and as soon as apparatus giving conclusive results is designed it will demand immediate consideration from the manufacturer and consumer.

German Substitutes for Burlap, etc.

In accordance with a request from the Research and Statistics Division of the War Department, an extensive investigation was carried on to determine the probable performance, suitability, availability of material, etc., of samples of German fabrics used as substitutes during the war. A complete analysis of the fiber contents was made to show that no new fibers and compositions were used, cotton and coniferous fibers (as used in paper making) being the principal contents. The results of the physical tests showed that the utilization of short and inferior fibers for a superior purpose was not practicable for the weight and volume of material allowable for a specific use.

The ingredients used as waterproofing and disinfecting agents were determined by chemical analysis. It is noted that the substitutes with cotton fibers contained approximately 40 per cent of sizing compounds of different characteristics and were presumably added for certain definite uses.

The analyses serve to indicate the great need of like attempts to develop substitutes, and point to the importance of paying particular attention to a study of the desired performance of a manufactured and finished commodity rather than an investigation of the raw material.

Manufacture of Denims at Atlanta Prison.

Through the efforts of the executive secretary of the National Committee on Prisons and Prison Labor, an extensive investigation was undertaken by this Bureau on which to base recommendations as to the best type and weight of denims to be manufactured, together with the necessary steps to change the mill at Atlanta for such manufacture. This mill is now making a large amount of ducks. It was decided to first obtain as large a number of samples of denims as possible from the various State and Federal institutions and prisons, together with information as to the kinds used, methods of purchasing, and a statement of the probable wear in terms of months; then to perform the necessary physical and chemical analyses which would result in tentative specifications of denims. The results of this work proved very satisfactory and helpful. Similar work using the above method of procedure has been started on materials such as sheeting and ducks. This cooperation can be taken as an example of what can be accomplished by the Bureau on receipt of requests of this nature from private concerns as well as Government organizations.

Specifications.

It has been found that several of the Government departments are buying the same general types of material, but under slightly different specifications. The slight variations from commercial fabrics are

often just sufficient to make necessary the manufacture of special fabrics for the Government. This, of course, limits the supply and increases the cost to the Government very materially.

In the past year, acting on the advice of the Bureau, some of the departments have eliminated these conflicting specifications and have adopted specifications for commercial cloths in their place. It is thought that this procedure should be followed, as there are very few instances where the requirements of the fabric under working conditions can not be successfully met by commercial fabrics.

A general form has been used in writing specifications in order to secure, in so far as is possible, a uniformity of Government specifications. In many cases it was found that the existing specification had been created without a thorough knowledge of what the characteristics of the fabric should be, and to prevent a failure occurring a much better fabric than was necessary was specified.

The Bureau has been following the policy of inviting the manufacturers to criticize all specifications before they are recommended to the department for use in purchasing supplies.

Cotton Fire Hose.—An investigation was made to determine what constitutes desirable properties in fire hose, and in cooperation with the rubber section specifications covering the manufacture and inspection of cotton fire hose embodying these characteristics have been written. These specifications will be published as a Bureau circular.

Plumbers' Oakum.—During the past several years the Panama Canal authorities have had difficulty in purchasing a plumbers' oakum which would successfully meet their requirements. The section was asked to furnish specifications which would insure the furnishing of the desired oakum. After an investigation, which included the analyzing of samples from the principal manufacturers of this material, specifications were furnished governing the manufacture and inspection of plumbers' oakum.

Meritas Composite Cloth.—Meritas composite cloth is used for the tops and sides of the covered Army trucks and is made by cementing two plies of cloth together with a flexible adhesive oil and waterproofing compound containing no rubber. At the request of the Motor Transport Corps the existing specifications were thoroughly investigated and several changes were recommended to insure a more uniform and better wearing fabric.

Cotton Bunting.—Acting on the advice of this section the Panama Canal authorities decided to purchase cotton bunting in place of wool bunting for use in the Canal Zone. Complete specifications governing the manufacture and inspection of cotton bunting were furnished by this section.

It is estimated that the use of cotton bunting will save the Panama Canal about 50 per cent of their annual expenditures for wool bunting and at the same time give an equally serviceable bunting.

Rubber Sheetings and Mechanical Rubber Goods.—At the request of the commanding officer of the field medical-supply depot and in cooperation with the rubber section of the Bureau specifications were prepared governing the manufacture and inspection of rubber sheeting for hospital use and for the cloth entering into the manufacture of mechanical rubber goods, such as air cushions, hot-water bottles, etc.

Work for Tariff Commission.

Over 100 samples of imported fabrics were submitted for complete analysis and physical testing by the Tariff Commission. In addition to these requirements one or more photographs were made of each fabric to show the yarn and fiber characteristics, the construction, and the design with color schemes. These data not only supplied information upon which rates may be based, but form a permanent record of each type and design of fabric submitted. The work has not been completed, but it is expected that it will be finished in about a month.

Flameproofing of Parachute Silk.

A number of specific tests were made on parachute silk treated with a solution of sodium tungstate to determine the extent of its fire resisting properties. At the request of the Director of the Air Service of the Army samples were made up and treated, and then observed on the application of flame. Results showed that inasmuch as the silk is composed of organic matter its destruction can not, of course, be prevented when any part of it comes in contact with a flame or a sufficiently hot substance; that the impregnation of sodium tungstate solution can serve to prevent the spreading of fire over the material when a flame comes in contact with any part of it; that the solution is removed by washing in water or when subjected to a heavy rain, thus necessitating the application of more of the solution if the material is to remain fire resistant; that a slight change in the physical properties was noted to the extent of 6 to 10 per cent loss in tensile strength and an increase in stretch of 10 to 20 per cent upon the application of the fire-resisting solution.

Further tests would give additional information, such as the effect of exposure to sunlight, storage, and use upon the impregnation of the silk.

Test Specimens for Tensile Strength of Ducks.

At the request of a commercial laboratory for the testing of textiles, a series of experiments were completed to show the relation of the single yarn breakage to the breakage of the fabric by the "strip" method of test, as recommended by the Bureau, and differing from the so-called "grab" method of testing the tensile strength of fabrics. The results pointed out more clearly the conclusions given in a publication previously issued by this section and entitled "The Strip Method versus the Grab Method in the Determination of the Tensile Strength of a Fabric."

Spanish Moss as a Mattress Filler.

A determination was made by physical tests of the suitability of "Florida" or "Spanish" moss as a substitute for other fibrous materials as a matress filler. The problem was submitted by the Division of Research and Statistics of the War Department. Careful consideration was given the subject and a comprehensive report was sent out giving the problem a tentative program, the results of which will be of great interest. Final conclusions were withheld because the test specimens were too small to give definite information as to the performance of the filler in a full sized mattress. Some of the

properties investigated were ease of manufacture, elasticity, resiliency, rate of absorption of energy, density, and tendency to cohesion of the individual fibers.

Investigation of Materials for Sandbags.

In cooperation with the paper section of the Bureau, a study of the requirements of sandbags as used in trench and barricade warfare was outlined, with special reference to the cost, availability, methods of manufacture, and durability when being transported and handled under all conditions of weather and location for a period of predetermined life. This work was undertaken at the request of the War Department, and this department is conducting the actual service tests. A description of the test methods can be found in the report of the paper section.

Sail-Canvas Investigation.

A short investigation was conducted at the request of the New York Yacht Club on specimens of canvases to be used as sail cloth for the American cup defender *Resolute*. A comparison was made of the cloth made for the defender's sails in 1914 with the cloth used in this year's sails. The results showed that one fabric had a slight increase in tensile strength, due to a longer-staple cotton and a slight change in the cloth construction. No appreciable loss in strength due to storage was noted in the 1914 fabric, showing that the method of storage was carefully considered by the club. Stress-strain relations indicated that the performance of both fabrics would be about the same.

Shade Cloth.

The contemplated purchase of shade cloth for the windows of the new industrial building of the Bureau warranted a request to this section for complete tests on specimens of the material submitted. Special attention was given to their fastness to light and also to the brittleness and elasticity of the filler whenever present. It was concluded that the resistance of the material to cracking should be considered as the quality next in importance to light fastness. Consideration was given to the construction of the fabric, fiber contents, amount of filler necessary to prevent the translucency of the shade, and period of serviceability. Investigations of this nature should aid the public in obtaining a more serviceable commodity. Plans have been made for continuing the work through the coming year.

Fish-Net Investigation.

A tentative program has been drawn up for an investigation of ingredients used to prolong the life of fish nets as used in the Great Lakes and other fresh waters of this country. The cooperation of the Bureau of Fisheries and an interested manufacturer of fish nets has been obtained. The results so far indicate that fish nets deteriorate very rapidly in fresh water. The causes appear to be bacteriological growth and repeated wetting and drying in usage.

Sizing Compounds.

Preliminary work has been started on the investigation of sizing materials for cotton yarns, and analyses have been made of these

compounds to determine their general applicability. In the process numerous samples of sized fabrics were examined for per cent of size and nature of ingredient used. Some of the fabrics were submitted as routine work, but the analysis was carried further for investigational purposes.

Cotton and Woolen Goods.

A large number of cotton as well as woolen fabrics were tested for percentage of fiber content, fastness of color, nature of dye, paying particular attention to the use to which the fabrics were to be put. Results were used in drawing up tentative specifications, which for the most part were requested by various Government departments.

Heating Pads.

At the request of a manufacturer tests were conducted to determine the shrinking effect of heat on heating pads. The investigation, although by no means an extensive one, brought out many facts interesting and essential to this particular manufacturer concerning the best materials to use to obtain the desired performance. These tests, however, were not representative enough to warrant any general recommendations concerning the manufacture of heating pads.

Routine Testing.

Over 3,300 samples were tested during the past year, principally from Government departments, of which the Panama Canal, War Department, Navy Department, and Post Office Department were the chief contributors. The tests covered the whole field of textiles, including fibers, yarns, and an unusual variety of fabrics as well as made-up materials, such as blankets, handkerchiefs, table linens, hosiery, etc. The analysis of 100 foreign fabrics imported from Belgium, Holland, England, Switzerland, and France and submitted by the Tariff Commission was of special interest. Considering the number of samples which have been tested and the care and accuracy necessary in their preparation, it is very evident that routine testing occupies an important place in the work of this laboratory.

TOTAL ROUTINE TESTING OF TEXTILES.

	Number of samples.	Fees.
Government	3,301	$7,939.50
Non-Government	72	298.50
Total	3,373	8,238.00
Estimate of routine testing in research problems		6,975.00
Grand total		15,213.00

PAPER.

This section is concerned with the development of methods of testing and with the preparation of specifications for paper of all kinds, especially in connection with paper for certain definite uses. This work is of benefit not only to the Government in the purchase of supplies, but also to the public and paper manufacturers.

Facilities.

The paper testing laboratories and the experimental paper machine have been moved to new quarters in the Industrial Building and the equipment and apparatus have been arranged in four groups or divisions. These groups consist of physical testing instruments, chemical apparatus, microscopical and photomicroscopical apparatus, and paper-making equipment. Due to the fact that relative humidity and temperature affect the physical properties of paper, a large room has been equipped with a conditioning apparatus to maintain 65 per cent relative humidity and 70° temperature. The physical tests on paper are made in this room under these standard conditions. A complete chemical laboratory and weighing room has been arranged for the necessary chemical tests on paper and these are equipped both for routine testing, and with apparatus used in research work.

Since fibrous material is the chief constituent of paper, it is necessary to study its physical characteristics by means of the microscope. This quipment is necessary, not only for identification and estimation of fibers, but also for the study of the characteristics of the fiber. The paper-making equipment has been somewhat rearranged and additional machinery has been obtained, which will materially assist in this branch of the work. The new equipment consists of a 300-pound concrete beater with necessary motor and stuff chests, a larger screen, a sheet cutter, and a supercalendar. This experimental paper mill, when fully installed, will probably be the best in the country for studying the factors which influence the quality of paper.

Tearing Strength of Paper.

During the past year, the tearing quality of paper has received considerable attention from industrial laboratories. This test is used in a rough way by the paper maker to determine the quality of paper. In the hands of an experienced man, it is often possible, by tearing the paper with the fingers, to get a very good idea of the characteristics of the paper. Additional work has been done on this test during the past year but the data are not yet complete. In developing a scientific method of reproducing to some extent the tearing of paper by hand, it is necessary to study the initial, the maximum, and the average tears, as these vary to some extent with different grades of paper. An attempt has been made to determine the relative accuracy of three testing machines available and also to develop a machine that will give data that may be interpreted to show the strain on the paper which tearing produces. Due to the method of making paper, its strength is not the same in the direction the paper runs on the paper machine as it is at right angles to this. In addition, when tearing some papers at right angles to the direction in which the paper was made, there is a tendency for the tear to be uneven and for part of the fibers to strip off. This must be taken into consideration, as it seriously affects the test. It appears from the data already available, that the size of the test sample used influences the test. It also seems true that not only is the strength of the fibers actually being torn or separated indicated by the tearing strength but also that of the fibers on either side of the tear to a considerable distance.

Paper for Lime and Cement Bags.

Additional work has been done on the study of paper for use as bags for lime and cement. This investigation was started some years ago and was discontinued during the war. During the past year, emphasis was laid on the development of the stress-strain test and the correlation of it with the drop test. The stress-strain test gives an indication of the resiliency of the paper under successive loads which are a constant factor below that which would produce rupture. Both the number of times the load may be applied before the sample breaks and the percentage elongation or stretch is taken into consideration. It is thought that the correlation of this test with service tests will greatly assist in the development of specifications of paper for this purpose.

Substitute for Sand Bags.

At the request of the War Department, an investigation, in cooperation with the textile section of the Bureau, was undertaken to obtain or develop a substitute for jute burlap for use as sand bags for military use. A material was desired that would be reasonable in price, which would resist weather conditions for at least six months, and which could be obtained in this country in large quantities in time of war. A number of samples of burlap, cotton fabric, plain paper, reinforced paper, and specially treated paper were obtained and tests were made in the laboratory to determine their relative value. From the data obtained, it was decided to eliminate all but five samples which showed promise of being of value for such work. These were a burlap, a cotton fabric, a cement bag paper, a paper reinforced with cotton fabric, and a waterproof paper, all manufactured commercially and available in large quantities. Bags of the proper size were bought made of these materials and tests were made with them filled with sand. These included the drop test and the jolting test. The latter one gave an indication of the weakness of the glueing or of the sewing of the bag. Samples of the materials were exposed to weather conditions on frames and were also buried in the ground. Both of these sets of samples were tested in the laboratory at stated intervals to determine their deterioration. The data so far obtained seem to indicate that a heavy paper made of old rope will be suitable as a substitute for jute burlap for sand bags. It is desirable, however, that this paper be made more water resisting and it is expected to make a study of the development of this quality.

Sizing Quality of Paper.

There are a large number of factors that influence the sizing quality of paper and, before going very far into this investigation, it was thought necessary to develop a method of determining this sizing quality. For some years the so-called conductivity method of determining this quality has been used to some extent for mill control work. As indicated in a previous report, it was thought advisable to make certain changes in the apparatus. During the past year, new equipment has been obtained and set up. It is now possible to determine the rate of penetration of an electrolyte through a sheet of paper and to obtain a curve which represents this changing rate. It is proposed to study the factors in the sheet of paper

which may affect this test and to correlate the data obtained with other tests of a more or less empirical nature. When this test is properly interpreted, it is planned to investigate the factors in the manufacture of the paper which may influence the sizing quality of paper.

Samples for Microscopic Estimation of Fiber Content.

It was found desirable to produce a new set of standard samples of paper to be used for the microscopic estimation of the fiber content of paper. Sixty-seven combinations of fibers were made up into 3-inch disks, in the proportions usually found in commercial papers. Due to the fact that commercial papers are beaten differently in different mills, it was not possible to reproduce this beating effect in the standard samples. The fibers were all sufficiently beaten to felt into a sheet of paper, but their characteristics were retained. The fibers used were rag pulp, coniferous and broad-leaf chemical wood pulp, ground wood pulp, and manila and jute pulps. Several sets of these samples have been sent to paper mill laboratories for comparison and criticisms.

Sulphate Pulp Identification.

During the last 50 years the manufacture of sulphate wood pulp, sometimes called "Kraft" pulp, has increased to such an extent that it is used to a very large degree in papers requiring considerable strength but where color is not important, such as wrapping and bag papers. When examined under the microscope, using the customary stain, it is difficult if not impossible to identify this pulp. The extended use of this material has made it desirable to develop methods, both for identifying it and for estimating the quantity of the material present. With this in mind, various stains and dyes have been tried in order to obtain one that will react selectively with sulphate pulp and other pulps with which it may be found. This work is nearing completion and a vast number of samples containing known and unknown amounts of sulphate pulp have been examined. The results of this work will be published in the near future and will be of great value to all laboratories and mills that come in contact with sulphate pulp.

Microphotographs of Fibers.

It has been possible to obtain a set of samples of authentic paper-making fibers, and microphotographs of these have been made. In the development of the methods of taking these photographs great improvement has been obtained and emphasis has been placed on clearness of definition and absence of background. For this work, additional apparatus has been obtained and developed, as it was found desirable to have a very long camera bellows. It is now possible to extend the bellows to either 15 or 20 feet and this permits of better definition and a flatter and larger field. The microphotographs produced are the equal of any appearing in print and are very valuable as showing the characteristics of various paper-making fibers.

Microscopy of Paper-Making Fibers.

During the last two years a great deal of work has been done on the methods and technic used in microscopy of paper fibers and the

proper use of the necessary instruments and apparatus. The routine estimation of various fibers in the samples of paper has been standardized to a large extent and the investigational work has been put on a firmer basis. It is proposed to produce in the near future a publication giving the results of the work on microscopy of fibers with data as to the proper equipment and methods which will be of value to industrial laboratories. The discussion of the methods will include the value and use of various stains for bringing out the characteristic markings of the fibers, and the pamphlet will be illustrated with microphotographs of paper-making fibers.

Paper from Unusual Fibers.

Due to the high price and scarcity of raw material for the manufacture of all grades of paper, especially newsprint and book papers, there has been an increased interest in the utilization of straw, grasses, and other fibrous material for paper making. The demand for information has become so great in certain cases that various fibrous materials have been examined and in some instances manufactured into paper. It is, however, to be regretted that in most cases those interested in the use of these fibers have assumed that if a sheet of paper can be produced in an experimental way, that the same thing can be done commercially. This is quite often true in so far as the actual manufacture is concerned, but seldom is it realized that the cost of the total operation is the chief limiting factor. Not only must there be a large uniform supply of raw material, but it must be within easy transportation distance; the cost of the preparation of the fibers into pulp must be sufficiently low and the grade of paper produced must have a market at a price that will allow some profit. Many of the grasses and fibrous materials receiving attention at this time have been investigated for a hundred years or more and very few have ever been successfully used on a commercial scale. The fibers examined during the past year are as given below:

Saw grass, spartina grass, Japanese cane, yucca plant, and flax straw were made into paper in various combinations, but these fibers were submitted already cooked and were not further treated. Rice straw, lalang grass, and banana stems from Siam were each made into paper and were found to have some value. The lalang grass gave a paper somewhat similar to that obtained from esparto. Bagasse fiber, cotton stalks, and bleached munition linters have also been used for manufacture into paper. But in practically all cases, as mentioned above, it is not the actual manufacture into paper that is the great difficulty. The collection of the material continuously in sufficiently large quantities, the cost of cooking, the low yield, and the grade of paper produced must be considered before planning to use these fibers on an industrial scale.

Mimeograph Paper.

The scarcity of paper and the difficulty of obtaining a sufficient supply for use in making mimeograph copies of data and information by this Bureau has led to the production of this grade of paper with the paper-making equipment. Two results have followed from this request for manufacture of mimeograph paper. In the first place, a paper was developed that was sufficiently "slack-sized" to permit of its use on the mimeograph machine and yet was ink-

resisting enough to permit its use when made up into pads for writing purposes. In the second place, during the process of manufacture considerable data are being obtained in regard to the factors influencing the quality of paper. These data will be properly collected and tabulated and should be of value. The new beater which is being installed will be especially helpful, as it was designed so that the factors influencing beating could be studied at will. The product of the mill in many of these experiments is used as mimeograph paper.

Specifications for Lime for Cooking Rags.

At the request of the Interdepartmental Lime Conference, specifications were prepared governing the requirements for a good grade of lime for cooking rags of the same grade for use in the manufacture of paper. The presence of dirt and grit is very undesirable, and one of the purposes of preparing rags for paper making is to eliminate all the nonfibrous material. Cooperation was maintained with mill laboratories, and the specifications were adopted by a technical committee of the paper industry. These specifications appear in full in Bureau of Standards Circular No. 96.

Routine Testing.

There are certain tests on paper which have been found available and sufficiently accurate to use in general work on most classes of paper. These methods have become standardized and are used in connection with most of the samples submitted for test. The equipment for such tests is always set up and is in constant use. To facilitate the work this group of tests has been called routine testing, and the routing of samples for such tests has been carefully worked out. For much of the investigational work these routine tests are necessary, and the term is of value mainly to distinguish standard methods from proposed or preliminary ones. During the year a total of 4,362 samples of paper were tested under this classification, of which 3,090 were submitted by Government departments and 1,272 by public and private interests.

Although routine testing is productive of but little fundamental data, it is at the same time of considerable assistance in developing specifications and in determining the accuracy of the instruments used in paper testing and in judging the uniformity of paper of given grades.

Miscellaneous Information.

During the past year a large amount of miscellaneous information in regard to the testing and manufacture of paper has been given through correspondence and conversation with visitors. There seems to be an increased interest in the testing of paper, and it has been necessary to make many references to data appearing in trade periodicals. For that reason it is planned to publish as soon as possible a circular on paper, its specification and testing, giving the common methods of procedure and the necessary equipment.

Information has been supplied to practically all the Government departments in Washington that would assist them in the proper purchase of paper. Some of these data were available, while in other

cases special work had to be undertaken to obtain the desired information. The paper-testing laboratories are always at the disposal of the Government departments, and an even greater cooperation would probably result in purchasing paper more consistent with the needs of the Government and with the customs and practices of the paper industries.

LUBRICATING OILS.

Standardization of Instruments.

A portion of this work includes an investigation of the Redwood viscosimeter, in connection with other viscosimeter comparisons. Mention of this research was made on page 113 of last year's report. For various reasons the work has been delayed and, therefore, but little progress can be reported.

A fuel oil viscosimeter, designed by George M. Saybolt, is at present under investigation, and a MacMichael viscosimeter, which is an instrument of the torsional type, has been thoroughly studied. The results of this work were published in volume 12 of the Journal of Industrial and Engineering Chemistry, for 1920, page 282. A less technical paper, prepared in collaboration with E. W. Dean of the Bureau of Mines, will soon be published.

Viscosity of Oil Blends.

In connection with the work on viscosimeters, tables and diagrams were prepared for estimating the viscosities of oil blends. This work is described in Bureau of Standards Technologic Paper No. 164 entitled "The Saybolt Viscosity of Blends" and a preliminary report on the same subject appeared in volume 22 of "Chemical and Metallurgical Engineering" for 1920, page 1109.

Friction Machines.

The new oil friction machine, mention of which will be found on page 113 of last year's report, is now in use, and two papers are in course of preparation which describe some results obtained with a friction testing machine recently bought in the open market.

Routine Physical Tests.

During the year physical tests were made on 1,193 samples of oils and greases. This very large increase in work, as compared with previous years, was principally, if not entirely, due to the great number of samples received from the War Department. There was an increase in spite of the comparatively few samples sent by the General Supply Committee. Usually, all of the samples of lubricants submitted with bids are sent for test. This year the committee agreed that only those samples for which demulsibility and carbonization tests were required, should be tested.

Chemical Investigations.

After many failures at intervals for several years, a satisfactory method for the determination of sulphur in petroleum oils has been devised. It gives results as good as those by the bomb calorimeter, and can be used in laboratories where that apparatus is not available.

A preliminary paper was published in the Journal of Industrial and Engineering Chemistry, volume 12, page 482, 1920. The manuscript of a more extended discussion of the subject was accepted for publication as a Bureau of Standards Technologic Paper.

Carbonization of Petroleum Oils.—This Bureau has already published four papers which have a bearing on what has come to be known as the Waters carbonization test. This is often confused with the Conradson carbon residue test. For this reason, and because of many requests for information about the two tests, a circular explaining the differences between the two is in course of preparation.

Routine Chemical Testing.

There was a large increase in the number of samples received for chemical examination. Most of these were also tested in the physical laboratory. Among these may be mentioned numerous samples of cutting oils received from the Public Health Service, which is making a special investigation of this subject.

Cooperative Work.

The chief of this section is the representative of the Bureau on committee D–2, on petroleum products and lubricants, of the American Society for Testing Materials, and cooperation is likewise carried on with the committee on standardization of petroleum specifications.

LIME, GYPSUM, AND SAND-LIME BRICK.

The work of this section has to do with the development of specifications for these materials, the improvement of manufacturing processes to produce better or cheaper materials, and the collection and dissemination of knowledge which will lead to their more efficient use.

Popping of Lime Plaster.

Unless lime which is used for plastering purposes is properly made and handled it is apt to pop. Small particles will hydrate after the plaster is set, will expand, and push themselves out of the wall, leaving small holes in the plaster. It is obviously essential that a test for this tendency to pop, or unsoundness, be included in the standard specifications for lime. Before such a test could be established as satisfactory it was deemed necessary to investigate the causes of the phenomenon.

Accordingly, a research on this subject has been conducted by the manufacture of plasters containing known amounts of suspected ingredients. These plasters were exposed to the air for a year and examined for signs of popping.

As a result, it may be stated that popping is caused by particles of chemical compounds which are formed by the union of certain impurities with the lime in the kiln. These compounds can be distinguished from lime by their appearance, and can therefore be sorted out. Small particles which escape the sorter can be taken care of by soaking the lime paste overnight before using. If the particles are all fine enough to pass a No. 48 sieve, and there are not too many

of them, they may pop without leaving holes large enough to cause disfiguration of the wall.

The final report on this subject has been released for publication to the Journal of the American Ceramic Society.

Chemical Lime.

More than half of all the lime produced is sold as chemical lime; that is, it is used as a reagent in the manufacture of other materials. Heretofore it has been customary for each purchaser of chemical lime to prepare his own specifications. This has led to great confusion in the industry. A certain quality of lime may be rejected by one purchaser as failing to pass his specifications and accepted by another purchaser using more lenient specifications, even though both parties are buying the lime for exactly the same purpose.

The Bureau has invited representatives of various other Government bureaus to meet with it and to draft recommended specifications for the various kinds of lime required by the chemical industries. Before publication of these specifications, they will be approved by the National Lime Association and by the corresponding national association of the users.

One specification has been issued—Recommended Specifications for Lime for Cooking Rags in the Manufacture of Paper, Bureau of Standards Circular No. 96. Three others are now in course of preparation.

The Use of Hydrated Lime in Concrete.

Many contractors make a practice of adding small amounts of hydrated lime to concrete. It has not yet been determined whether or not this practice is justifiable. In 1915 the Bureau organized an advisory committee, composed of representative cement manufacturers, lime manufacturers, engineers, and contractors, to assist it in planning a research on this subject. During the past year a complete series of 4-year-old specimens were tested. Thus far the committee has failed to agree on what constitutes a fair basis for the comparison of concretes with and without lime, and the publication of test data is therefore postponed. It is felt that possibly the criterion should be the working quality of the concrete. An investigation to determine how this quality can be measured is now under way.

Measurement of Plasticity.

Finishing hydrate, which is used for the third or white coat of plaster, sells for about $2 a ton more than other kinds of hydrated lime. It differs from other kinds solely by reason of its greater plasticity. Plasticity is therefore a property having great economical importance, and a requirement for it must be included in the specifications for finishing hydrate.

A method of measuring the plasticity of lime has been developed by the Bureau. A description of the machine used is given in Technologic Paper No. 169. We are now collecting numerical data so that fair limits may be established for the plasticity of finishing hydrate.

The Bond Between Mortar and Sand-Lime Brick.

Competitive salesmen, in attempting to prevent the use of sand-lime brick, have stated that the brick does not bond well with mortar. The Bureau was asked to investigate the truth of this statement, and also to find out whether or not the bond could be improved by any change in the character of the brick or of the mortar.

It was found that the bond between brick and mortar is surprisingly weak, and this statement is not confined to sand-lime brick. The bond can be improved by careful control of the wetness of the sand-lime mixture before it is pressed into bricks, and by properly wetting the bricks before laying them.

During criticism of this report within the Bureau, the fact was developed that, theoretically, the strength of the bond between brick and mortar is of very minor importance in determining the strength of the finished masonry. This theory was corroborated by further experiment and, by recalculation of the data given in Technologic Paper No. 111.

The final report was presented at the 1920 meeting of the Sand-Lime Brick Association, and will be published in their proceedings.

Time of Curing of Sand-Lime Brick.

Sand-lime bricks are made of sand and lime, mixed, pressed, and cured with steam. The usual practice in the United States is to use steam at 100 to 150 pounds pressure for from 7 to 12 hours. Laboratory experiments indicated that a brick will attain nearly its full strength in four hours, and that the strength gained by longer hardening is not sufficient to be economical. During the past year, five manufacturers have cooperated by curing their bricks for different lengths of time and sending them to the Bureau for test. As a result of this work, six hours has been established as the most economical time for curing the bricks. The adoption of 6 instead of the present 7 to 12 hours will mean a considerable saving of both time and fuel, without detriment to the quality of the product.

A report on this subject was read at the 1920 meeting of the Sand-Lime Brick Association and will be found in their proceedings.

The Acoustics of Wall Plasters.

The question of acoustics, especially of public auditoriums and of apartment houses, is becoming a very serious and important one. It is generally conceded that much of the trouble caused by the reflection and reverberation of sound is due to the design of the room, but it is also suspected that the character of the walls may have something to do with it.

To investigate this point, the Bureau has undertaken to measure the quantity of sound transmitted, reflected, and absorbed, by all of the usual types of wall construction. Twenty-one panels, each 4 feet square have been prepared. These represent all usual types of backing, such as different kinds of masonry and of lath; different types of plaster such as lime and gypsum; different types of finish, such as smooth troweled and sand floated; and different types of after treatment such as papering and painting. No tests of their acoustical properties have yet been made.

Colored Plaster.

From the viewpoint of both the architect and the owner, the usual dead white color of a wall plaster is not satisfactory. Several attempts have been made to produce tinted plaster by the addition of some pigment to the plastering material. These have not been successful because it is almost impossible to match the tints of different batches and the line of demarcation between work done at different times is therefore glaringly pronounced, and also because plaster colored in this way is still dead—the texture is displeasing.

The Bureau has produced an unlimited variety of colors and textures by the use of gypsum wood-fibered plaster. The wood fiber is dyed the desired colors before being mixed with the gypsum. By scrubbing the surface of the plaster after it has set, these fibers can be made to stand out from the wall more or less distinctly, thereby producing both color and texture.

A report on this subject is now in course of preparation.

Conference on Plastering.

In most city building codes the specifications for wall plaster are either very lax or entirely missing. To remedy this defect the Bureau has organized a conference for the specific purpose of writing a National Plastering Code. It is hoped that this work will be of such quality that it will be accepted as a guide by the city legislators when they frame their own laws on this subject. The conference is composed of official representatives of the Portland Cement Association, the National Lime Association, the Gypsum Industries Association, the National Association of Sand and Gravel Producers, the National Brick Manufacturers Association, the Hollow Building Tile Association, the National Lumber Manufacturers Association, the Associated Metal Lath Manufacturers, the National Association of Plastering Contractors, the International Plasters' Union, the American Institute of Architects, the National Fire Protective Association, and the Supervising Architects Office of the Treasury Department.

The work is well under way. The first chapter, having to do with the preparation of masonry surfaces to receive plaster, is about ready for the final action of the conference.

Physical Tests of Gypsum.

Certain methods of test for gypsum have been adopted as tentative standards by the American Society for Testing Materials. In order to write specifications for gypsum, it is necessary to know the numerical limits for the different properties, as measured by these standard methods. To obtain this necessary numerical data, the Bureau has measured the chemical composition, fineness, normal consistency, time of set, compressive strength, tensile strength, and yield of 43 samples of commercial gypsum products.

This report is now (July 1, 1920) in the hands of the Bureau's editorial committee.

Standards for Design of Reinforced Gypsum.

Tests of plain and reinforced gypsum beams, made between 1914 and 1916, led to the formulation of standards for the design of rein-

forced gypsum. These standards have been published in the 1919 Proceedings of the American Society for Testing Materials, volume 19, part 1, page 349. Based upon this investigational work, there has been manufactured and brought into use several millions of square feet of reinforced gypsum tiles. This is a structural roof tile used for supporting the ornamental tiles or other roofing materials. In practice it varies in span from 2½ feet to about 10 feet. Some of its advantages are (*a*) lightness, (*b*) speed in construction, (*c*) the furnishing of a noncondensing surface for use in places where large amounts of moisture are present in the air, and (*d*) its resistance to fire.

The Cracking of Gypsum-Block Partitions.

Gypsum block is a comparatively new building material. In accordance with the usual custom, therefore, any failure of a partition built of gypsum block is immediately blamed on the block without further investigation. If the block does really cause cracking, the public should be warned; if it does not, the block manufacturer should have definite facts to combat the calumny.

The expansion and contraction of individual blocks when wet and dry, hot and cold, loaded and not loaded, have been measured. A partition 22 feet long by 10 feet high by 3 inches thick has been built of gypsum blocks. Careful measurements of this partition and of the concrete beams above and below it are being taken at frequent intervals, so that if the partition does crack we shall have sufficient data to tell why.

Cooperation with the American Society for Testing Materials.

The work of the American Society for Testing Materials is chiefly the preparation of specifications for materials, through special committees appointed to handle the individual subjects.

This section holds membership in committee C–3, on brick. It holds membership in committee C–7, on lime, and the chairmanship of subcommittee 2 on structural lime and subcommittee 6 on plasticity. It holds the chairmanship of committee C–11, on gypsum.

All of these committees meet frequently, and the Bureau is called upon to develop test data for their use.

Visits to Lime and Gypsum Manufacturing Plants.

In order to keep in close touch with the new developments in the industry, and to obtain a first-hand knowledge of the problems confronting it, the practice has been started of making personal visits of inspection to the manufacturing plants. During the past year 28 lime plants and 1 sand lime brick plant in Maryland, Virginia, and the District of Columbia have been inspected. Complete descriptions of the plants, illustrated with photographs, are kept on file for future reference.

8. METALLURGY.

The metallurgical division concerns itself with research, investigation, and testing as related to metals and alloys except metal structures and the processes of extraction of metals from their ores. Its functions include the production of metals and alloys, both of the highest attainable purity and of commercial grades; the preparation and study of auxiliary metallurgical products, such as slags, included gases, molding sands, refractories, and deoxidizers; the development of apparatus, instruments, and manufacturing appliances for metallurgical processes, research, and testing; the formulation and maintenance of those standards and specifications of interest to metallurgy; the determination of metallurgical constants and properties; the investigation of the performance of manufacturing units; the determination of the causes of failure and the study of the improvement of metal products; and the development of economical metal substitutes. The division has equipment for metallographic examinations of metals, such as microscopic analyses, including determinations of constitution, structure, and causes of failure; for thermal analyses, including determination of heating and cooling curves for location of critical points; for the various heat treatments, such as annealing, quenching, cementation, tempering; for various operations for the hot and cold working of metals, such as forging, rolling and drawing, and for miscellaneous physical tests; for the usual foundry operations of molding and casting ferrous and nonferrous metals; and for other metallurgical processes, such as production of pure metals, electrodeposition and plating, welding, and determination of gases in metals.

MICROSCOPY AND STRUCTURE.

Relation of Grain Size to Mechanical Properties.

Coarsely grained metals are usually regarded with suspicion and alarm by users, though when pressed to the point but few are able to give definite reasons for this distrust. A study has been started to show the relation of the mechanical properties of steel to the grain size of the same. As a measure of the "static" properties the Brinell hardness was used, and the results of this part of the study have already been summarized and presented for publication. Grain size appears to be of very minor importance compared with other factors which affect hardness.

The work will be extended to cover the effect of grain size upon the "dynamic" properties as measured by some form of the notched-bar impact tests.

Conditions Affecting the Hardness of Carbon Steels.

This study was planned partly to supplement the above; it is also intended to make a close, careful study of the microstructural changes which occur in hardened steels upon tempering. The data available in the literature on this phase of the metallography of carbon steels are rather meager. By magnetic means, by thermal analysis, and by a study of the physical properties of steel after tempering it can be shown that pronounced changes occur in the steel. The microstructure does not show changes correspondingly as pronounced, hence the need for a more careful study of steels in the hardened-and-tempered condition.

Intercrystalline Brittleness of Metals.

Metals sometimes develop a characteristic embrittlement so that they can be easily crumbled into powder; the individual particles, however, retain all the intrinsic properties of the metal. Such embrittlement may be due to various causes. The reason for such embrittleness in lead has been studied to considerable extent. (See Publications.) An unusual case of the embrittlement of copper has also been described. Such embrittlement usually occurs as a result of some form of corrosion, and a series of experiments have been carried on to determine whether this embrittlement readily occurs during the corrosion of the common soft metals—lead, tin, aluminum,

etc. These experiments are still in progress; it appears, however, that embrittlement most readily occurs if the specimen is subjected simultaneously to corrosion and to a tensional stress.

Metallographic Etching Reagents and Methods.

A rather comprehensive study of the subject of the etching of metallographic specimens has been started in order to show what principles underlie successful etching. This phase of metallographic study has been developed in a rather empirical manner in the past. The first metal to be considered in the investigation was copper; the results of this study are ready for publication. The successful etching of copper depends upon two factors: There must be a slight solvent action and an accompanying oxidation. By varying the intensity of either of these two factors an "etching" varying from one showing bald contrast in the shades and colors of the different grains to a simple etching in which the grains all appear alike may be obtained. The work is still in progress and is being extended to the other metals and alloys.

"Deep Etching" as a Means for Metallographic Study.

This item was mentioned in last year's report as having been started. The study was continued during the year, and the results obtained have been published. Deep etching as a means of macroscopic examination is of value in showing the following important features: (1) Chemical inhomogeneity (segregation, etc.), (2) mechanical nonuniformity (an internally stressed condition), and (3) physical discontinuities (flakes, internal fractures, etc.) within the steel.

Structure of Iron and Steel at High Temperatures.

A knowledge of the structural condition existing in iron and steel at high temperatures is essential to a proper understanding of the changes which accompany the hardening of steel by quenching. Such a study has been carried out during the past year. The structure existing at high temperatures was revealed by the means of "heat etching" the polished face of the specimen; after heating in vacuo at the desired temperature and then cooling in the evacuated furnace, markings appear which are characteristic of the structural changes it has undergone during the heating. It is unnecessary to use any etching gaseous medium at the high temperature, as has usually been done in similar investigations.

The heat-etched specimens show a carbonless layer at the surface, the thickness of which depends upon the conditions of heating. Some further work has been planned in order to show the "mechanism" by which this decarburization in vacuo is brought about.

The Rôle of Manganese in Steel.

As part of the investigation of deoxidizers for steel, a study is being made of a series of steels of widely varying manganese and carbon contents. The aim of this part of the work is to show how the structure of the iron-carbon alloy is affected by the presence of different amounts of manganese. The specimens used will be taken from bars for which the usual mechanical properties have been determined.

Zirconium and Other Special Alloy Steels.

The study of the microstructure of "zirconium" and other special alloy steels suitable for the development of light armor plate has been completed. It was the aim of the investigation to demonstrate the rôle which zirconium and titanium play in such steels in the endeavor to explain the effect of additions of these elements on the mechanical properties of the resulting steel. It appears that neither zirconium nor titanium alloys with the steel but act as "scavengers." When not eliminated in the slag they remain in the metal as inclusions. Of the other rare elements that were tried, cerium and uranium go into solution in the steel while boron forms a complex eutectic which is fusible at the temperature usually used in rolling. A survey was also made of the microstructures of the plates in the normalized and heat-treated states. This acted as a check upon the soundness and heat-treatment of the plates, and in most cases served to explain unexpected mechanical properties.

Flaky Steel.

The examination of the type of defective steel designated as "flaky steel" was continued during the year. The results obtained, however, do not add materially to our knowledge of the cause of this defect in steel. Experiments with rolling steel of this character in the Bureau's experimental mill showed that the flakes still persisted after a reduction of 50 per cent. This was true regardless of whether the rolling was in the direction of the defect or at right angles to it.

Conditions of Pearlite in Steel.

This investigation, mentioned in last year's report, has been completed. It was concerned principally with the structural conditions resulting in various grades of carbon steels after cooling the heated specimen through the critical range (800–650° C.) at widely varying rates. As an indication of the mechanical properties of the materials the hardness was determined. The results are now being assembled for publication.

Effect of Phosphorus in Low-Carbon Steels.

A series of low-carbon steels (0.12 per cent carbon) with phosphorus varying in a series of five steps from 0.008 to 0.115 per cent have been used in this study. The aim is to determine the effect of the phosphorus upon the microstructure after annealing, the specimens being cooled at known rates through the critical range. The mechanical properties, as indicated by the Brinell hardness, are also determined. The steels used are those described by Dr. J. Unger, Carnegie Steel Co., in Iron Age, 1918, and represent both acid and basic open hearth practice. The investigation is still in progress.

Electric-Arc Welding.

Though seriously handicapped in the study of welding by several resignations during the year, a rather comprehensive study of the properties of the "weld-metal" of electric arc welds has been made. A large number of specimens of arc-fused metal were prepared from two of the types of metallic welding electrodes now used for the pur-

pose, of a size large enough to permit a study of the characteristic properties of the material being made. This study included the determination of the mechanical properties, the changes induced in the chemical composition by the fusion, and the examination of the microstructure of the fused material. Particular attention was given to the subject of nitrogen in such material, the condition in which it occurs, its determination, and its elimination. Electric-arc welds are essentially castings and should not be used for any purpose for which a casting would be unsuitable. The results of the investigation have been summarized and submitted for publication as a technologic paper.

Copper Crusher Plugs.

The results of the experiments on copper crusher cylinders conducted so far have been prepared for publication. As a result of the research completed there have been drawn up four specifications covering the standardization of pressure gauge method of pressure testing of ammunition and powder, as follows: (1) For copper rods to be used in the preparation of pressure gauge cylinders, (2) for the preparation of pressure gauge cylinders, (3) for the calibration and precompression of copper cylinders, (4) for standard methods of making pressure tests.

HEAT TREATMENT AND THERMAL ANALYSIS.

New Equipment.

Several small heating units have been added during the past year to the experimental heat treating plant and an automatic temperature control pyrometer has been purchased. The section is now well equipped with a number of heating furnaces of a variety in size and design enabling efficient heat treatment of carbon, alloy structural and high-speed tool steels, and also nonferrous metals and alloys to be carried out.

Effect of Heat Treatment on Properties of Structural Steels.

There is in progress a series of investigations to determine the effect of heat treatment on various physical properties of carbon and alloy structural steels. One of this series, namely, stainless steel, containing 0.20 per cent carbon and 13 per cent chromium, has been completed, while progress is being made on others as outlined below.

One Per Cent Carbon Steel.—Tests are now in progress to determine the effect of time and temperature in both hardening and tempering on structure, tensile properties, hardness, and impact resistance of a 1 per cent carbon spring steel.

Three and One-Half Per Cent Nickel Steel.—This investigation consists of a correlation under varying thermal treatments of tension, compression, torsion, fatigue, and impact properties as determined by various types of testing machines, with structure. Considerable data are available concerning this widely used steel, but there is no known correlation of mechanical properties such as is being attempted. The actual work involved is now about half completed, but no conclusions have been drawn. It is expected that this investigation will be completed during the coming year.

Carbon Chromium Steel.—An investigation on the effect of heat treatment on the compressive strength and wear resistance of a steel containing 1.10 per cent carbon and 1.40 per cent chromium is now under way. This steel is largely used in the manufacture of balls and races in ball bearings and the tests contemplated, comprising compression, impact, and wear resistance, should be of particular interest to this field.

Molybdenum Steels.—Steels containing molybdenum are again arousing considerable attention for use as structural materials, particularly as considerable deposits of ores of this metal are to be found in this country. A series of tests on various alloy steels to which molybdenum has been added has been started to determine the effect of heat treatment on structure and tensional and impact properties.

High Chromium Steel.—The experimental work in this investigation has been completed and a paper published in the July Journal of the Society of Automotive Engineers and in the July 7 issue of Chemical and Metallurgical Engineering.

The following features are of particular interest: Samples of a high chromium steel of the following analysis, C 0.29 per cent; Mn 0.38 per cent; Si 0.70 per cent; and Cr 13.2 per cent, quenched in oil from various temperatures show (1) that with increasing quenching temperature hardness as measured by Brinell and Shore instruments increases until a temperature of about 1,950° F. (1,066° C.) is reached. Maximum range of hardness is generally obtained by quenching from this temperature up to the highest heat used, but in some cases this hardness actually decreases due to retention of the solid solution; (2) that quenching from about 1,750° F. (955° C.) develops the best combination of strength and ductility which is not coincident with range of maximum hardness. Quenching from this or lower temperatures does not retain all the carbide in solution as is the case in samples quenched from considerably high temperatures (notably 2,100 and 2,250° F.) (1,149 and 1,232° C.); (3) and that ductility as measured by elongation and reduction is very low in those samples quenched from 1,850° F. (1,010° C.) or above.

Short-time tempering at temperatures up to about 800° F. (427° C.) of samples previously quenched from both 1,750° F. (955° C.) and 2,100° F. (1,149° C.) decreases brittleness. However, ductility is increased to a greater extent in those samples quenched from 1,750° F. (955° C.) than in those quenched from the higher temperature.

Tempering above 800° F. (427° C.) markedly decreases strength values and hardness, which is of course accompanied by greatly increased ductility. In general, the structure of the hardened steel tends to persist even when tempered for a short period of time at temperatures comparatively close to the lower critical range, the characteristics depending upon the quenching temperature used. The most rapid change in tensile properties and hardness occurs in tempering between about 800° and 1,000° F. (437° and 538° C.).

Tensile Properties of Steels at High Temperatures.

During the year a special apparatus was designed and constructed for the determination of the proportional limit at elevated temperatures. Over 300 tensile tests of boiler plate of various grades and under varying conditions of work and thermal treatment were made at temperatures up to about 460° C. A preliminary report of the

first two series of tests has already been published by the American Institute of Mining and Metallurgical Engineers, and another and more complete publication is expected within the coming year. Tests on marine and two grades of fire-box boiler plate have been completed. Plates have also been tested as cold rolled and quenched and tempered in various ways. A modification of the apparatus using a motion-picture machine for obtaining stress-strain diagrams at rapid rates of loading at elevated temperatures has also been constructed and used with success.

Confirmation of generally accepted changes in tensile strength, elongation, and reduction in area were found. Tests further show that proportional limit does not decrease with temperature rise, as has often been stated, but that this factor "holds up" throughout a definite temperature range and in some cases increases before final decrease occurs.

Rate of loading from less than 0.01 inch per minute to 1.6 inches per minute has practically no effect on the tensile properties (including position of proportional limit at temperatures up to and including the blue-heat range about 295° C.). At 466° C. some interesting changes take place. Further work confirming these results is now being carried on.

Bluing of cold-worked steel (annealing for a short time at 295° C.) markedly increases the ratio of proportional limit to tensile strength. Similarly, low temperature annealing of steel rolled at a blue heat (295° C.) does not show this effect. These experiments are being continued.

Heat Treatment of Carbon Steel.

In cooperation with the National Research Council and the Bureau of Mines, an investigation has been begun to increase our knowledge of the production of sorbite, both by determining the limits of the sorbitizing conditions and by showing the influence of the more important variations of the tensile and impact properties of the resultant sorbite. Material treated consists of seven-eighth-inch rounds of acid steel, with carbon contents 0.34, 0.52, and 0.75, and above 0.50 manganese. They are being heat treated under especially favorable conditions for effect of reproduction and the resulting properties of material determined. It is expected to be able to report substantial progress the coming year.

Behavior of Hardened Carbon and Alloy Steels on Heating.

Determination of the effect of heating previously hardened carbon steels has been made. A thermal transformation act coincident with precipitation of the carbide held in solution by the previous quenching has been investigated and a publication has been prepared. Considerable progress has also been made in determination of the effect of various alloying elements such as Mn, Si, Mo, W, Co, etc., on this transformation.

High-Speed Steel.

Preparations have been made to obtain a small lot (about 10 pounds) of high-speed steel from 10 manufacturers of high-grade standard high-speed steel. Seven have already complied and six samples are at present undergoing chemical analysis. The purpose

of this investigation is to obtain accurate information as to the proper heat treatment of high-speed steel and to correlate such data with the composition; it is planned to include determination of fusion temperature and degree of secondary hardening. Such information should be of considerable importance in aiding in the explanation of the effect of the several alloying elements and the reasons for their control within the usual narrow limits of practice.

Gauge Steels.

A preliminary series of length and flatness measurements covering six months has been completed on several hundred artificially seasoned steel precision gauges of varying compositions subjected to various treatments. Results obtained have not proved satisfactory as the changes in individual gauges subjected to the same treatment are inconsistent in most cases, which seems to approximate conditions in use. Continuation of this work during the year is contemplated.

High-Speed Cutting Alloys.

Determination of the tensile properties of several so-called high-speed alloys at elevated temperatures is also in progress with the view to correlating cutting efficiency with properties more simply determined, giving if possible an index to the relative values of various steels (or of the same steel after various treatments) as cutting media for specific purposes.

Thermal Analysis.

Considerable progress has also been made in various investigations where determination of thermal transformations is the principal method employed. These are as follows:

Iron carbon alloys.—The experimental determination of the thermal transformations of pure iron-carbon alloys of fundamental importance in the heat treatment of steels (as outlined in the last report), has been completed and a publication is now in preparation.

Nickel Steels.—Experimental work and a publication covering the effect of nickel up to about 5 per cent on the occurrence of the thermal transformations has been completed.

Embrittling Effects of Cleaning and Pickling Upon Carbon Steel.

This investigation, described in last year's report, has been completed and an account of the results read before the April meeting of the Electrochemical Society and will appear in the fall in a forthcoming technologic paper. The embrittling effects were obtained for plain carbon steel rods by the alternating stress method and of plates by the Erichsen penetration method. The effect of cleaning, sand blasting, pickling, and treatment after pickling were studied.

WORKING OF METALS AND MISCELLANEOUS PROPERTIES.

Bearing Metals.

During the latter part of the year a start has been made on the bearing-metal program mentioned in the annual report for 1919. Apparatus has been designed and constructed for determining the

proportional limit in compression, compressive strength, and Brinell hardness at elevated temperatures. Results have been obtained for these properties of the bearing metals included in the revised specifications of the Society of Automotive Engineers at temperatures of 25°, 50°, 75°, and 100° C. and are now being prepared for publication.

A review of the literature on bearing metals has been made and a bibliography compiled. This, together with some miscellaneous tests on bearing metals, will also be published shortly. Other items on the program will be taken up as fast as the vailability of funds and personnel permit.

New Foreign Alloys.

Through the courtesy of the Bureau of Foreign and Domestic Commerce and the Department of State the Bureau has had opportunity to study some recent alloys developed abroad and for which most remarkable claims have been set forth in the popular and technical press. Tests made at the Bureau do not show these materials, most of which are aluminum alloys, to possess any superiority over American made alloys, and in many respects are inferior.

Acid-Resisting Alloys.

Tests of typical acid-resisting alloys of the silicon iron type exposed to the action of various acids and salt solutions at atmospheric and elevated temperatures are in progress. Since the exposures are relatively long and the hot tests can be conveniently made only during the winter months, when the steam supply is continuous, the results of this investigation will not be available for several months. Mechanical and physical properties of the materials are also being determined.

Cushman Zinc-Coating Tester.

A study was made of the original form of an apparatus devised by Dr. A. S. Cushman for determining the weight of zinc coating on galvanized sheet. The apparatus consists of a bowl held tight to the sheet which contains a solution of antimony chloride in hydrochloric acid and an inverted burette to collect the gas set free by the reaction. The results were quite variable and inaccurate, due to the irregular expansion of the entrapped air. The apparatus has since been improved by Dr. Cushman to eliminate this error, and in its present form is a very convenient and rapid device for determining the weight of zinc coatings.

Equilbria of Tin Rich Ternary Alloys.

An investigation was made of the ternary alloys high in tin, of tin-copper-lead, tin-copper-zinc, tin-copper-antimony, tin-lead-zinc, tin-zinc-antimony, and tin-lead-antimony. Freezing point determinations were made on these alloys, which contained from 0.1 to 1.0 per cent of each of the elements added to the tin. Some of the alloys contained equal amounts of the impurities and others unequal amounts. From the freezing-point determinations, diagrams showing the freezing points of each system of ternary alloys were made from plaster of Paris and these models photographed. The freezing-point determination showed that the effect of the impurities was not individual, additive, or substractive. They also indicated the

effect of the impurities on the freezing point of tin as used in the testing of fusible plugs. A few photomicrographs were taken of each of the series of ternary alloys showing typical microstructures. A publication is in course of preparation.

Metal Specifications.

Assistance has been given to Government departments and technical societies in the formation of specifications for metallic materials. Mention may be made of the Navy Department, War Department, Panama Canal, District of Columbia, Society of Automotive Engineers, American Society for Testing Materials, and the National Advisory Committee for Aeronautics. An interdepartmental committee has requested the Bureau to act as a clearing house for specifications, and to this end a complete file of all Government specifications and many commercial specifications is being collected.

New Equipment.

The following new equipment of interest has been acquired during the year: 50,000-pound Amsler universal testing machine, Farmer alternating stress machine, Stanton alternating impact machine, Amsler wear-testing machine, 200-pound wire-testing machine, and an Ewing extensiometer.

Precision Altimeter.

In cooperation with the aeronautic instrument section an altimeter of unusually high precision has been developed. This altimeter has a range of 10,000 feet and a maximum error, due to hysteresis of 20 feet, or 0.2 of 1 per cent. The drift and after effect are negligible. This instrument was made possible by the development of a steel spring of exceptional qualities having a maximum deflection without exceeding the true elastic limit of the material used.

It is expected to publish soon a report covering the development of this instrument and precautions to be followed in the design of similar instruments.

Rolling and Forging of Metals.

The following metals have been rolled during the past year; forty ingots of zirconium steel rolled to one-half inch plates, 69 ingots of iron alloys rolled to one-half inch plates, boiler plates rolled cold and at "blue heat," specimens of flaky steel forged and rolled, and specimens of steel annealed in vacuo.

Two hundred pounds of lead in the form of 50-pound pigs were forged and rolled to sheet 0.03 inch thick for the Research Laboratory of the Signal Corps. Samples of these and other sheets were annealed at various temperatures and duration in an effort to determine the best procedure for producing lead for some electrolytic cells.

Emissivity of Monel Metal and Constantan.

At the request of the International Nickel Co., the emissivity of several samples of molten monel metal was determined. Five observations were made in an atmosphere of CO_2 with the micropyrometer. The emissivity was found to be 0.40 ± 0.01 at 1,400° C. with a wave length of 0.65μ.

The emissivity of constantan with the same conditions was found to be 0.38. Observations of monel metal heated in air, giving an oxide surface, gave a value of the emissivity of 0.70±.02 at 1,200° C.

Rolling-Mill Investigation.

In this investigation the effects of the properties of hot-rolled steel produced by variations in some factors of the process of rolling are to be determined. The factors to be varied are: Reduction per pass, total reduction, finishing temperature, initial temperature, and speed of rolling. Observations will be made on the power consumed by the mill with the different conditions of operation thus produced.

The effects on the mechanical properties of the material are to be observed by longitudinal and transverse tensile, impact, Brinell, and scleroscope hardness tests on each sample in the rolled condition and after normalizing. Fatigue tests will also be made on some of the samples. Observations will be made of the density of the material as cast and with various conditions of rolling. Examinations of the microstructure will be made to assist in the interpretation of the results.

Physical Properties of Pure Nickel.

The object of this investigation is to determine the physical properties of pure nickel; to date the determinations have been only on samples which can not be classed as pure nickel, although melting-point determinations to some extent have been taken on pure nickel. Following successful working of pure nickel, the determination of the following physical properties is planned on material as cast, forged or drawn, and annealed: critical points, density, linear expansion, electrical resistance, and mechanical properties. Material for this work is being prepared by the International Nickel Co.

Corrosion of Aluminum Alloys.

Exposure tests were made at the three navy yards, at Portsmouth, Norfolk, and Pensacola, of sheets of aluminum, duralumin, and various other metals, both painted and unpainted, to determine the resistance to sea-water corrosion between sand and water. The results of these preliminary experiments are somewhat in doubt due to the unexpected presence of fuel oil on the sea-water surface. The aluminum and duralumin plates showed very little corrosion to these conditions and the effect of painting was negligible.

RAILROAD MATERIALS.

Steel Rails from Ordinary and Sink-Head Ingots.

The opportunity was given by the Pennsylvania Railroad Co. to carry out an investigation of the quality of steel rails from various types of ingot with the cooperation of two steel companies. This work is in press as a Bureau technologic paper.

The research involves a comparison of 100 tons of Hadfield sink-head ingots and of ordinary rail ingots as made by the Maryland Steel Co. with three methods of manufacturing steel, and includes a chemical, physical, and metallographic survey of the ignots and of

the blooms and rails made from them. It was found that sound rails free from piping and segregation with a very small discard could be made from the sink-head ingot. This type of ingot appears to be much more satisfactory for making sound rails than that of the ordinary type, cast with the small end uppermost.

Chemical analyses and sulphur prints of split ingots and blooms, metallographic investigation, and a large number of the usual mechanical tests are included in the report. Several tests by the Pennsylvania Railroad Co. showed no breakages in two years.

Cast Iron for Locomotive-Cylinder Parts.

The former United States Railroad Administration requested the Bureau to investigate the quality of cast iron used in locomotive packing rings and other cylinder parts subject to the action of superheated steam. The Railroad Administration procured a number of rings made by different foundries with service mileage records, as well as arbitration test bars and chill test blocks, also from various makers.

The resutls, which have gone to press as a Bureau technologic paper, indicate that on the average air furnace iron, because of its somewhat better quality and more uniform character, is more suited for cylinder parts than cupola iron.

Existing specifications have been revised so as to make the mechanical requirements more rigid and assures the use of only the highest quality of iron. The Bureau believes that as long as the materials meet the requirements of the specification the consumer need not be concerned with the melting process employed.

Thermal Stresses in Chilled-Iron Car Wheels.

The experimental work on thermal stresses induced in chilled iron car wheels by heating of the tread similar to that caused by brake action has been completed. Records of the railroads indicate that a very large percentage of car-wheel failures are due to heating of the tread in service, the hub of the wheel remaining relatively cool. It was the purpose of this investigation to determine and recommend for use the most suitable material and design for iron car wheels. Fifty wheels were used for the investigation.

In these experiments the tread of the wheel was heated by passing an alternating electric current through a circular steel resistor insulated from the tread. The wheel remains stationary, thus facilitating the taking of the necessary temperature and strain gauge readings.

A large percentage of the wheels cracked in the test, indicating it to be more severe than service conditions. An interesting and significant development of the work was that the high sulphur wheels showed a much higher percentage of failures than those of lower sulphur content. The results in detail will soon be published as a Bureau technologic paper.

Thermal Stresses in Steel Car Wheels.

It has been decided to conduct an investigation of steel car wheels similar to that of iron car wheels. On June 17, 1920, a meeting of the representatives of manufacturers, one railroad, and the Bureau was held at Washington. At this conference the results of the tests of iron wheels were discussed, and as a first step it was thought de-

sirable to first duplicate on steel wheels the tests of iron wheels. Both new and used wrought and cast steel wheels are to be tested.

Graphitization of White and Gray Cast Iron.

It has been found necessary to continue the Bureau's work on the graphitization of white cast iron upon annealing. This problem arose in connection with other investigations on the properties and characteristics of chilled iron car wheels, and in particular, the best range of annealing temperatures. The composition of the wheel is so chosen and the wheel so cast that the tread and inside of flange show white iron and the remainder graphitized or gray iron. In order to relieve the stresses set up during the cooling of the wheel under drastic conditions, the wheels are piled in pits and allowed to cool slowly; investigation developed the fact that the highest temperature at which no graphitization of the tread and flange takes place is about 720° C., which is also the maximum annealing temperature for car wheels. Arrangements are being made to determine the effect of annealing at low temperatures for a prolonged period of time.

Electric Furnace Cast Iron Experiment.

The problem of refining molten cupola iron in the electric furnace has been brought to the attention of the Bureau by the Association of Manufacturers of Chilled Car Wheels. The Bureau first plans to remelt low quality scrap with the object of determining the quality of the product. Chill tests and the usual mechanical and chemical tests will be made. The small Heroult electric furnace is admirably adapted to this type of research.

Sulphur and Phosphorus in Steel.

During the war it was found practically necessary to permit the use of steel for railroads and other purposes containing larger amounts than was considered desirable of the detrimental elements, phosphorus and sulphur. At the request of the former United States Railroad Administration and the American Society for Testing Materials, an elaborate program has been prepared by a joint committee of which the Bureau has the chairmanship, and on which practically all of the larger technical societies of the country are represented. It is the object of the investigation to determine the maximum permissible amounts of phosphorus and sulphur for the various classes of steel. The question has been under discussion for some time and it appears that the specification-making organizations, such as the American Society for Testing Materials, are lacking in sufficiently exact scientific knowledge to determine in rational terms the fixed limits of these elements in steels for various purposes. On account of the present unsatisfactory fuel and scrap situation the problem is one of acute importance, especially in the reference to sulphur.

Under the auspices of the joint committee on the investigation of sulphur and phosphorus in steel, a beginning has been made in the collection of statistics concerning the behavior in service of steels containing unusual quantities of sulphur or phosphorus and the following program of tests has been laid out.

SERIES A TESTS.

SULPHUR IN ALL STEELS TO BE "RESIDUAL SULPHUR."

[All compositions are expressed in hundredths of per cents.]

Group No.	Material.	Carbon.	Manganese.	Phosphorus.[1]	Sulphur.[1]
1	Rivet steel, tubes, etc.	6–12	35–40	2–3 4–5 6–7	3–4 5–6 7–8
2	Plates and structural shapes, including boiler plate.	16–22	35–40	3–4 5–6 7–8	3–4 5–6 7–8
3	Forgings, such as car axles, treated and untreated.	45–55	50–60	3–4 5–6 7–8	3–4 5–6 7–8
4	Wheel, tire and rail steel.	65–75	60–70	3–4 5–6 7–8	3–4 5–6 7–8
5	Spring steels.	95–105	35–45	2–3 4–5 6–7	3–4 5–6 7–8
6	Castings	Compositions to be considered later.			

[1] With each of the specified ranges of phosphorus it is understood that the sulphur content is to be constant and equal to the usual value for that group of material. (Vice versa for sulphur.)

SERIES B TESTS.

In these tests higher percentages of phosphorus and sulphur than are specified in Series A tests shall be used. The purpose of this series is to carry the tests beyond the percentages of impurities specified in Series A to a point where the material will unquestionably fail from the effect of the higher impurities.

There have been made for the committee 12 tons of rivet steel, part of which has been made up into rivets and part into bars of varying sulphur content which are now being tested in the Government laboratories at Watertown, Annapolis, and the Bureau of Standards. There have also been made under the class B series three heats of steel of three carbon contents, each consisting of eight sulphur contents, totaling 63 tons, from which it is expected to obtain evidence as to the effect of sulphur both as added between the ladle and the ingot and as residual in the heat.

CHEMICAL METALLURGY.

Iron-Carbon-Manganese Alloys.

The preparation and analyses of ingots of the original series planned for this investigation have been completed; also a partial second series of similar composition for heat treatment. Most of the bars for mechanical test have been prepared and several of these have received final heat treatment preparatory to mechanical test. Magnetic test specimens have also been prepared.

Direct Method for Determining Nitrogen.

The work described in the last annual report on a new method for determining nitrogen as such or in mixtures with other gases has been continued on an increasing scale and the apparatus brought to its final form. As a result of improvements thus effected, the time

required for a determination has been reduced to less than two hours. It is expected this investigation will be published during the coming year.

Nitrogen in Weld Metal.

Determinations of "combined" nitrogen by the Allen method, as modified in the Bureau, have been made on samples of weld metal deposited by the arc under experimentally varied conditions. Determinations have also been made on the same samples after heat treatment in vacuo and under ordinary atmospheric conditions. Very large amounts of "nitride" nitrogen (up to 0.15 per cent) have been found. These are reduced somewhat by heat treatment, especially in vacuo. It is planned to make total nitrogen determinations on these same samples, using the new direct method for this element that has been developed in the section on chemical metallurgy.

New Design for Arsem Furnace Heater.

The heater heretofore used in the Bureau's Arsem furnace is a carbon spiral, which is fragile and is usually ruined if molten iron comes in contact with it, as frequently happens. To obviate this difficulty a tubular heater was built up of superimposed carbon rings, these being mounted in the ordinary electrode holders used in the Arsem furnace. Preliminary trials of this furnace have been successful. Such heaters were used and described by Rosenhain at the National Physical Laboratory for furnaces working in reducing or inert atmospheres, and the results here show that the design is equally well adapted to vacuum furnaces. A paper describing this furnace is being prepared.

Ladle-Test Ingot Research (in cooperation with the A. S. T. M.).

Ten steel companies are cooperating in the work this year. The purpose of the work now in progress is to investigate more completely the findings of the last report, namely, that the addition of aluminum to ladle-test ingots while they are being poured eliminates segregation regardless of shape and size of ingot. Each of the companies is preparing ingots from heats of carbon steels with varying compositions, first, according to its usual practice and, second, by the usual practice except that aluminum is added. Six of the companies have completed their work. When all the ingots have been received they will be examined chemically and physically at the Bureau and elsewhere.

Aluminum.

The work previously reported on preparation of pure aluminum has continued and several specimens have been made under varying conditions. The electrically heated furnace for maintaining the cryolite bath in the molten condition was very successful and some methods were developed for purifying the raw materials beyond the point reached by the manufacturers. It is expected to continue this work next year.

Total Gases in Steel.

During the year a new method has been developed for this work, which aims to dispense with sample collecting or other complicated

mercury pumps. The gases liberated from the molten steel are aspirated through a suitable set of weighed absorption tubes connected to a simple mechanical vacuum pump. Tests of this method on gas mixtures of known composition have given very good results.

Special Refractories.

A considerable amount of work has been done on refractories necessary for the special requirements of the section, particularly in the use of zirkite alone or mixed with other materials and various binders for crucibles and gas-furnace linings. The method for making magnesium oxide by calcining the sulphate has been fully developed and has superseded other methods used in the section for this purpose. In order to obtain the oxide entirely free from sulphur it has been found desirable to leach it with water after calcination. This material is now prepared and used in relatively large amounts for the alloy work.

Deoxidizer Investigation.

The first phase of the cooperative research on this subject with the National Research Council and others has been completed and is about to appear in the technical press. In this work 73 possible new deoxidizing alloys were discovered, and the preparation of these is now initiated. When made they will be tried out in the Bureau's experimental steel-making furnace and elsewhere.

New Equipment.

The Ajax-Northrup furnace mentioned in the last report has been used in many phases of the alloy work and is to have further application in the work on gases in metals. A new Arsem furnace, using the modified Rosenhain heater previously mentioned, has been added to the equipment for this work. Additional capacity for making electrolytic iron has also been provided. The small furnace (run as an open-hearth furnace) for steel melting has been installed and operated.

FOUNDRY.

Experimental and Practical Castings.

During the past year there has been a marked increase of service given by the foundry to the Bureau and research laboratories of other Government departments in the preparation and making of a great variety of kinds and types of metal and alloy castings. The total estimated value of castings furnished during the year was $7,395. During the year there were made 1,946 castings from 401 patterns.

Molding-Sand Investigation.

The various commercial grades of foundry sands are being studied and include sieve tests, determination of optimum water content, permeability, and melting points, in order to determine their fitness for foundry purposes.

Weathering of Art Bronze.

An investigation is being carried out in cooperation with one of the statuary manufacturers as reported in the last annual report.

The purpose of the research is to determine the relation of the composition of statuary bronzes to the facilities with which they assume patinas on exposure to weather. The specimens have been undergoing weathering for some four years.

Electric Melting Furnaces.

The two electric furnaces which form part of the equipment of the metallurgical laboratory have been put to practical tests and found successful in manufacturing iron and steel for alloy-steel research. It was found to be possible to conduct in these furnaces refining processes as in any electric furnace.

There have been also manufactured several "Invar" pendulum parts.

Government Bronze and Its Substitutes.

The results of the first series of tests on substitutes for Government bronze have been published and a second series has been begun and is still under way, using 88–10–2 and 88–8–4 as a basis. Additions were made of Al, Fe, Sb, Mn, Ni, Mg, etc., to determine the effect upon the physical properties of such alloys. The work has not progressed sufficiently to show any definite results; it is expected to complete this during the coming year.

MILITARY PROBLEMS.

Light Armor Plate.

This investigation, which was carried out in cooperation with the Bureau of Mines and the Navy Department, has been completed during the year, and a publication dealing with the results obtained is in preparation. The work was undertaken primarily to determine the effect of zirconium as an alloying element in steel and indicates that the addition of zirconium does not increase the mechanical properties of the steel above that obtainable with cheaper and more simply manipulated alloying elements. Much the same statement applies to the use of molybdenum, uranium, cerium, boron, and copper in this type of steel. The most consistently good results were obtained with a steel containing from 0.40 to 0.50 per cent carbon, 1 to 1.30 per cent silicon, 0.80 to 0.90 per cent manganese, and 3 to 3.5 per cent nickel, with the possible addition of a scavenging element as vanadium. Such a steel gave a tensile strength exceeding 300,000 pounds per square inch, yield point of 250,000 pounds per square inch, with an elongation of 10 per cent and reduction of area of 35 per cent. About 165 heats of steel produced at the Bureau of Mines Experiment Station at Ithaca, N. Y., have been rolled into plates at the Bureau, heat treated, and the various properties determined. Twenty-eight heats submitted by a manufacturer were also included. Ballistic tests are being conducted on the material by the Navy Department.

Machine-Gun Erosion.

During the past year a number of machine-gun barrels furnished by the Ordnance Department were subjected to various tests to throw further light upon the relative abrasive action of the bullet and the gases upon the bore. Examination of barrels fired for varying num-

ber of rounds to and beyond a so-called life limit reveals the importance of both the abrasive action of the bullet and the gases. This series of tests has also included the intentional cracking of small specimens by means of an electric arc. A paper covering this preliminary work is now in preparation.

Continuation of experiments to determine more exactly the abrasive action of the bullet is contemplated during the coming year. A series of 21 steels of varying compositions was made up into billets and specially treated and are now undergoing ballistic tests by the Army Ordnance.

Copper Crusher Gauges.

This study, which was mentioned in the last annual report, has been completed and the results embodied in specifications which have been tentatively adopted by the Ordnance Department.

Metal Spraying.

An investigation of the latest devices for metal spraying is now under way and new designs for such appliances are to be worked out.

Manufacture of Victory Medals.

In cooperation with the chemistry division and the Quartermaster Corps of the Army a member of the metallurgical staff visited plants of manufacturing jewelers in Seattle, Wash., and St. Louis, Mo., who were about to produce Victory medals, which are to be given to all American participants in the World War. The metal to be used was inspected and advice given in regard to the manufacture and coloring of the medals.

German Motor Trucks.

The Motor Transport Corps has requested the Bureau to study the quality of the materials used in the construction of a large number of German motor trucks which were either captured during the war or turned over to the United States Army after the declaration of the armistice. Although the examination is not yet complete, the parts so far studied do not differ greatly from similar parts produced in this country. No remarkable substitute materials have been noticed, although in the majority of cases it is impossible to determine whether the trucks were constructed before or during the war.

RESEARCH AID TO MANUFACTURERS.

The following will give an idea of the kind of research aid it has been possible to give manufacturers during the past year. The list is not complete; but a few of the typical cases only are given.

Wrought Monel-Metal Parts.

It was shown by suitable microscopic examination that the defects which were suspected as being developed by service conditions were initially present in the metal and had persisted throughout the shaping of the piece. The persistent character of the "work line" in nickel alloys and their relation to the defects in the specimens under examination rendered the explanation one of absolute certainty.

Die-Casting Pins.

Steel parts used for die-casting parts often quickly deteriorate in service, due to the formation of a network of "alligator cracks," very similar to those formed in the erosion of the bore of gun barrels. Any grade of steel will ultimately deteriorate under the application of heat and pressure. The examination of the particular specimens submitted showed, however, in this case that defects initially present in the steel (ferrite streaks, inclusions, etc.) were sufficient to account for the abnormally short life of the parts.

Saw Blades.

A comparison of small jewelers' saw blades of present American manufacture with similar blades of prewar foreign make was requested by a large firm of jewelers. The examination made clear that the American saws were made apparently without a clear understanding of the purpose for which they were intended. Though of a different composition from the foreign-made blades, it was shown that by proper heat treatment a material improvement could be brought about.

A series of band-saw blades were submitted by another manufacturer. The examination showed that steel of a very inferior quality had been used, probably unknowingly. The defects in the blades were the direct result of similar defects present in the steel from which they were rolled.

Tinned Plate.

A series of specimens of "tin plate" of American make intended for export trade for the canning industry, but rejected by the purchasers as unsatisfactory were submitted for test. The examination showed that the steel sheet used as a base was of very inferior grade, and in most cases had received insufficient heat treatment for the stamping and other forming operations for which it was being used.

Automatic Knitting-Machine Needles.

Prior to the war the majority of automatic knitting-machine needles were imported from Germany, and during the war considerable difficulty was experienced in producing satisfactory needles in this country, although at present at least one manufacturer is making needles superior to the German ones. At the request of one of the manufacturers the Bureau is making a study of the various makes of needles in order to determine what qualities the needles must possess in order to prove satisfactory in service and so that specifications for their manufacture can be formulated.

Manufacture of Automobile Crank Shafts.

At the request of a maker of 6-throw automobile crank shafts the process of manufacture was studied with the idea of eliminating certain difficulties which had been encountered. It was found that much of the trouble was of a mechanical rather than metallurgical nature, although opportunities were found for various improvements in this end of the process. A report, giving the Bureau's conclusions in the case, was issued for the benefit of the manufacturer interested.

GENERAL ACTIVITIES.

Metallurgical Tests.

During the year the division makes a great many tests for both parties inside and outside of the Bureau, some of an elaborate nature and others being of a routine nature.

Fusible Boiler Plugs.—Six hundred and fifty-five fusible plugs were tested for the Steamboat-Inspection Service; of these 418 passed the requirements, 191 were rejected, and 46 were reported for having loose fillings. Of the 191 unsatisfactory plugs, 114 were rejected for having mare than 0.30 per cent Cu; 26 for having 0.30 per cent Cu and 0.10 per cent Pb; 16 for having more than 0.10 per cent Pb; 6 for having more than 0.30 per cent Cu and more than 0.10 per cent Pb and a trace of bismuth; 4 for having more than 0.10 per cent of Fe; 24 for having melting points below 230° C. and 1 for having sand in the tin filling.

Stainless Steel.—Samples of stainless steel for use for parts exposed constantly to sea water were examined. The test included microscopic examination, heat treatment, and exposure in a corroding atmosphere of a series of typical stainless steels. The results indicated that steels of a high chromium content were most resistant to corrosion and also that when in the hardened (heat-treated) state the attack was less than when in the soft (annealed) condition.

Cast-Iron Locomotive Packing Rings.—A large number of these were examined for the Railroad Administration. The results of the microscopic examination with those of the other tests made were embodied in the publication on this subject.

Steel Casting.—The examination of a large steel casting intended for a rudder frame which broke during transportation showed that although the material had received the specified heat treatment for refining, the coarse "casting structure" still persisted. This was due to the impurities present. Heat treatment has no effect upon the relocation of these; they remain in their original distribution and so the material retains to a large extent the original properties of the cast material.

Use of Cyanide Baths for Hardening.—A series of examinations for one of the departments of the Government of soft plates designed as "casehardened in cyanide" showed that no appreciable hardening results from the cyanide. The vigorous water quenching which follows the heating in the cyanide bath is sufficient to account for the hardness. The function of the cyanide, as thus used, appears to be the prevention of scaling or oxidation of the carefully prepared surfaces of the soft steel plates.

Among other examinations made may be mentioned the splitting of antimonial-lead-cable sheathing due to streaks (apparently of oxidized material); the progress of corrosion of thin castings of aluminum alloy used on seagoing hydroplanes, copper rotating bands, wrought-iron parts, in the endeavor to determine whether "single" or "double" refined; the failure of airplane turnbuckles due to the use of steel of a highly streaked character; steel bayonets of different designs; articles claimed to be of "sterling silver" composition; bearing metals which had deteriorated in service; cop-led bearing metal; roman metal; special steel, aluminum, and cast-iron

solder; lamp socket shells; aluminum casting alloy; monel metal and B. & M. bronze, etc.

Table of Test Items.—A list of the total number of tests made for Government departments, the Bureau and outside concerns is given in the accompanying table. The total estimated value of all tests made for the past year is $13,100.

	Heat treatment and thermal analysis.		Metallographic (including physical, chemical, and corrosion) tests.				Fusible plugs.	Total.
	Irons and steels.	Non-ferrous metals.	Irons and steels.	Aluminum alloys.	Brass and bronze.	Miscellaneous.		
FOR THE GOVERNMENT.								
Bureau of Standards	834	400	58		1			1,293
Emergency Fleet Corporation					2			2
Navy Department			3	6	2			11
Panama Canal			12		4			16
Steamboat-Inspection Service							655	655
War Department	311	76	5	1		1		394
Treasury Department			6					6
Post Office Department	1							1
Coast and Geodetic Survey		48						48
Bureau of Engineering			1					1
National Advisory Committee		25						25
Bureau of Engraving and Printing			1					1
U. S. Railroad Administration			38					38
Total	1,146	549	124	7	9	1	655	2,491
FOR THE PUBLIC	2		11	2	6	1		22
Grand total	1,148	549	135	9	15	2	655	2,513

Circulars of Information.

There is now going through the press a circular of information on nickel in which has been assembled all the available information as to the manufacture and properties of nickel and of its most important alloys. This forms one of a series of which copper and aluminum have previously appeared. There has also been issued a circular letter on high-speed steel, giving information as to its composition and physical characteristics and performance for various grades of this material.

Cooperation with Technical and Scientific Organizations.

The members of the metallurgical division have maintained active relationship in the work of several national scientific and technical organizations, including the National Advisory Committee for Aeronautics; the National Research Council; the American Institute of Mining and Metallurgical Engineers, which held a highly successful symposium on pyrometry October last; the American Society for Testing Materials; the American Physical Society, Engineering Standards Committee; Society of Automotive Engineers; and the Reclassification Commission.

Ordnance Detail and Visitors.

During the past year several men (from three to four) from the Ordnance technical staff have been constantly at work in section 1 of this division. These men have been working upon problems as-

signed to them by the technical staff, while the Bureau has furnished most of the facilities for carrying out the work, although the ordinary supplies and some of the apparatus were furnished by the Ordnance Department. The following problems may be listed as typical of these investigations: Determination of the hardness of cartridge brass shells by means of the micro-Brinell testing set; the study of fractures of gun steel and its correlation with the structure of such steel; the structure and treatment of steel cores for armor-piercing bullets; the structural changes produced by ammonia in steel.

During the year a representative of a large machine shop has spent some time at the Bureau working upon the problem of the conditions affecting the hardness of carbon steels.

Upon the request of the Spanish Embassy, the Bureau granted permission to Dr. Emilio Jimeno-Gill, professor of chemistry of the University of Oviedo, to undertake research work on the problem of "The relation of grain size of carbon steel to mechanical hardness."

Mr. Yamanchi, representing the South Manchurian Railway, applied through the Japanese Embassy for permission to study along the line of metallurgy at the Bureau. The request was granted and Mr. Yamanchi assisted in carrying out the work on the problem of the mechanical properties of a high chromium steel under varying thermal treatments.

Mr. Franklin K. Bell obtained permission through Dr. Owens, of Johns Hopkins University, to use the facilities of the Bureau and made up a rather complete series of the iron-copper alloys.

Travel.

During the year a three-months' trip abroad was taken by a member of the staff for the purpose of obtaining information on the subject of suitable and proper limits for sulphur and phosphorus in iron and steel. Both France and England were visited, the greater part of the time being spent in England. The effort was made to get in touch with the users of steel products—particularly railway materials as well as manufacturing and scientific metallurgists. Advantage was taken of the opportunity to visit scientific laboratories, particularly those engaged in the study of metals.

Members of the division were given the opportunity to attend conferences and meetings on scientific and technical subjects.

Typical Micrographs on Exhibit.

Micrographs in the form of large transparencies, typical of the various metals and alloys, have been prepared as a permanent exhibit in the metallographic laboratory.

Correspondence.

The metallurgical division carries on an extensive correspondence on metals and a typical list of the most interesting items is that given for the month of October, 1919, as follows: Tests on electric steels; alloys suitable for duplication of patterns; properties of a new ferrous alloy; alloys suitable for use in fusible plugs; use of pure zinc in galvanizing; improvement of metallographic micro-

scopes; aluminum castings; testing of alloys; effect of phosphorous on steel castings; problems in chain manufacture at Boston Navy Yard; preparation of standard steel samples; rebabbitting shaft boxes; malleable iron industry; tempering of copper; British Non-Ferrous Research Association to National Research Council; new processes for making aluminum solder; hardness of nickel and nickel-chromium steel; research in a possible new aluminum alloy; qualities of electric steel; performance of Ajax induction furnace; information relating to zirconium and zirconia; furnishing pure iron; preparation of manganese and other ferrous alloys; pure manganese; transformations in alloy steels; procuring and testing car wheels; annealing of car wheels; automobile babbitt metal; detecting gold in the ground; flux for soldering brass; solder of intermediate melting point; stainless steel; bario metal; light aluminum alloys; testing of foundry clays; books on forging; apparatus for transformation point determinations; cooperation with rolling mill research; boiler plate investigation; metallurgical problems suitable for doctor's dissertation; zirconium steel research; submarine periscopes; investigation of alloy "trialoyium"; specification for pressure reducing valves; determination of hydrogen in steel; expansion of brass in rifle shells; heat treatment of duralumin; Shimer case hardening process; heat treatment of galvanometer pivots; sulphur and phosphorus contents in steel; bronze castings; manufacture of monel metal; high melting point alloys; data on production of metals; absorption of gases by iron and steel; comments on aircraft metals specifications and on ordnance metals specifications.

Conferences.

On May 17 there was held at the Bureau a conference between representatives and an advisory committee of the American Foundrymen's Association. There were discussed several research problems of interest to foundrymen, which it was desired to have the Bureau continue work upon, such as molding sand standards, the determination of the thermal conductivity of sand molds, mold finishings, sand casting and the cleaning of castings, and shrinkage values and characteristics for various types of casting, a determination of oxygen in cast iron, and the metallography of inclusions in cast iron.

On June 17, 1920, representatives of the steel car wheel manufacturers and one large railroad system met at the Bureau, where a demonstration was made of the Bureau's apparatus for testing thermal stresses in chilled iron car wheels, and a tentative program was formulated for tests of steel car wheels, which are to be furnished by all the large manufacturers. Both new and used rolled and cast steel wheels are to be tested.

Two meetings have been held at the Bureau of the nonferrous alloys committee for the purpose of advising with the Bureau on its experimental program and in outlining investigations on such alloys. Among the items of research urged upon the Bureau were the following: (1) Corrosion, (2) bearing metals, (3) characteristics and properties of cores and core oils. These meetings are of particular value to the staff of the Bureau, as they offer the opportunity for an interchange of experience on subjects relating to metallurgical research of particular interest to the nonferrous metal industry.

A conference on copper crusher cylinders was held at the Bureau on September 8, at which representatives of the War Department (Ordnance and Arsenals), powder manufacturers, and the Bureau were present. A set of specifications for copper cylinders and instructions were tentatively adopted.

Several conferences were held during the year, resulting in the formation of a joint committee on investigation of sulphur and phosphorus in steel. This committee, having to do with the question of enormous economic importance not only to one of our largest basic industries and to all consumers of steel but to all the community, was finally organized on June 23, 1919, with the following cooperating bodies: United States Bureau of Standards, chairman; United States Railroad Administration (replaced by the American Railway Association); War Department; Navy Department; American Society for Testing Materials; Society of Automotive Engineers; Society of Naval Architects, Marine Engineers; National Research Council; Association of American Steel Manufacturers; Steel Founders Association of America; American Foundrymen's Association. A systematic program of investigation has been laid out and excellent progress made in the execution of the investigation.

Publications.

The following publications have appeared during the past year:

Report of the Pyrometer Committee of the National Research Council, G. K. Burgess, A. I. M. M. E., Sept., 1919.

Metals for Pyrometer Standardization, C. W. Waidner and G. K. Burgess, Bull. A. I. M. M. E. (Aug., 1919), No. 152, p. 1511.

Metallographic Features Revealed by the Deep Etching of Iron and Steel, H. S. Rawdon and Samuel Epstein, Tech. Paper 156.

Nature of the Defects Revealed by the Deep Etching of Transversely Fissured Rails, H. S. Rawdon, Report 85 to Rail. Com. Am. Ry. Assn., Nov., 1919. and Chem. and Met. Eng., 22, p. 505.

A Study of the Deterioration of Nickel Spark Plug Electrodes in Service, H. S. Rawdon and A. I. Krynitsky, Tech. Paper No. 143, A. I. M. M. E. Bull., 152 (1919), p. 1323.

Microstructure of Iron and Mild Steel at High Temperature, H. S. Rawdon and H. Scott, Sci. Paper No. 356, Min. and Met. (Feb., 1920), No. 158, Sec. 18. Chem. and Met. Eng., 22 (1920), p. 787.

A Peculiar Type of Intercrystalline Brittleness of Copper, H. S. Rawdon and S. C. Langdon, Tech. Paper No. 158, Min. and Met. (Feb., 1920) Bull., 158, Sec. 19.

Intercrystalline Brittleness of Lead, H. S. Rawdon, Sci. Paper No. 377, Min. and Met. (Feb., 1920) Bull., 158, Sec 7.

Applications of Metal Radiography, H. S. Rawdon, Proc. A. I. and S. Inst., 1919 (October meeting).

Contemporary Foreign Opinions on Sulphur and Phosphorus in Steels, H. S. Rawdon, Chem. and Met. Eng., 22 (1920), pp. 609–612.

Contribution to Discussion of "Shattered Zones in Certain Steel Rails," H. S. Rawdon, A. S. T. M. Proc., 1920 (June).

Manufacture and Properties of Light Wall Structural Tubing, H. J. French, Bull. A. I. M. M. E. (Sept., 1919), No. 153, p. 1855.

Tensile Properties of Boiler Plate at Elevated Temperatures, H. J. French, Min. and Met. (Feb., 1920), No. 158, Sec. 15.

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9. CERAMICS.

This division is concerned with the study of the principles involved in the production of the many kinds of clay products, such as the various structural materials, pottery, electrical porcelain and refractories, the manufacture of the different types of glass, including that used for optical purposes, and the enameling of metals. Owing to the fact that these industries are of basic importance in the development of the country and have not yet received systematic technical study the prosecution of researches tending to assist in the more rapid expansion of these industrial activities is of considerable importance.

CLAY PRODUCTS.

Use of American Clays in the White-Ware Industry.

The results obtained in the cooperative investigation conducted with the United States Potters' Association have been published in the Journal of the American Ceramic Society, volume 3, No. 2, 1920. It appears from the conclusions drawn that American kaolins are suitable for the manufacture of white-ware pottery, but that the production of the primary kaolin needed is as yet not large enough to satisfy the demand, and therefore the importation of English kaolin must be continued until the resources of the country are fully developed.

Paper Clays.

An extensive study has been undertaken of the properties of paper clays, their fineness, plasticity, absorbing power, strength, and their viscosity when treated with various sizing agents.

American Clays Suitable for the Manufacture of Graphite Crucibles and Glass House Refractories.

A Technologic Paper, No. 144, has been published on this subject, which gives the results of tests made upon a considerable number of domestic clays. It has been shown that there are available many American clays which are well adapted to these uses, and that it is not necessary to resort to imported materials.

Clays from Palestine.

A series of clay samples collected in Palestine have been submitted for tests for the purpose of determining their suitability for the manufacture of structural materials needed in the reconstruction of the country.

Study of the Drying of Clays.

The increased demand for more rapid manufacturing methods has made it desirable to study the maximum speed with which different clays may be dried, and also the relation between the rate of heating and the contraction. It has been found that the more rapid the heating proceeds the smaller is the observed shrinkage.

Study of the "Water Smoking" of Clays.

The increasing use of the tunnel kiln makes it necessary to establish the maximum rate at which clays may be heated during the initial stage of the firing when the residual mechanical and hygroscopic water is expelled. It has been found that clays may be heated much faster than is generally supposed and that there are two critical temperatures, about 100° and 225° C., which must be considered during this process.

The Effect of Aluminum Chloride Upon Clays.

It has been the practice in some porcelain works to add small amounts of aluminum chloride to the body mixture for the purpose of improving its working quality. Tests, involving the addition of aluminum chloride to kaolins and ball clays have been made and it was found that the reagent improved the strength of the kaolins in the dry state, but not of the plastic clays. The addition of aluminum chloride to porcelain compositions low in ball clay is therefore justified. Larger additions, 0.1 per cent or more, seem to bring about an undesirable condition in the plastic state, detrimental to satisfactory molding.

Addition of Potassium Ferrocyanide to Clays.

The comparatively small amount of colloidal ferric oxide and hydroxide present in the plastic clays imparts to them a yellowish cast undersirable for paper-making purposes. It was thought desirable to determine whether the color could be neutralized by the addition of potassium or sodium ferrocyanide. It was found that this reagent brought about an improvement in the color and this method might hence be employed for treating certain kaolins.

Function of Caustic Soda Added to Clays.

In the purification of clays through deflocculation by means of caustic soda the function of the reagents and especially the degree of its absorption by clay has not been known. The amount of alkali absorbed by the clay was therefore determined for several kaolins and found to be practically constant.

Tests of Feldspar and Flint.

Considerable variation exists as to the fineness of the commercial grades of flint and feldspar offered on the market and also with refer-

ence to the fusibility and color of the feldspar. Tests have been made of a large number of commercial samples and the results may be used as a basis for specifications for materials so essential to the pottery industry.

Effect of Ground Quartz Upon Plastic Clays.

The use of ground quartz (potter's flint) is more or less common in diverse ceramic industries and more definite knowledge concerning its effect upon the drying and burning, shrinkage and porosity after firing is essential for the intelligent use of this constituent. The properties mentioned were determined for three typical ball clays with additions of ground quartz varying from 0 to 50 per cent. The rate of decrease in shrinkage and increase in porosity with increasing proportions of flint was thus established.

Mechanical Strength of Typical Clays.

No systematic information concerning the strength of the different types of clay used in the fabrication of the cruder structural materials is available. This situation made it necessary to conduct tests upon a number of typical shales and clays consisting in firing bars made from them to a series of temperatures and determining the transverse strength for the different stages of burning. The graphical presentation of the results is of interest in showing the increase in strength with increased heat treatment and is useful in making possible specifications for the testing of clays. The transverse strength was used as a criterion due to the fact that in use structural products are usually subjected to stresses of this kind and not to pure compression or tension.

Properties of Fire Brick.

Technologic Paper No. 159, published during this year, gives the results of tests of fire bricks with reference to their fusibility, resistance to load, contraction in volume, and decrease in porosity. About 60 well-known brands of fire brick have been studied and the results are of value to users of clay refractories.

Transverse Strength of Fire Clay Tiles at 1,350° C.

Owing to the dearth of information concerning the effective strength of fire-clay tiles used so largely in furnace and coke-oven construction an investigation has been begun for the purpose of computing the modulus of rupture and the deformation of standard refractory tiles for different spans.

Structural Terra Cotta.

In cooperation with the National Terra Cotta Society a large number of terra cotta mixtures have been tested for contraction, porosity, and transverse strength when fired to seven temperatures. In addition the resistance to disintegration of these bodies after repeated immersion in a sodium sulphate solution and subsequent drying was observed. From a study of the results tentative specifications for terra cotta have been proposed, subject to revision after additional work has been done.

A study of the thermal coefficient of expansion of the terra cotta bodies of the country is now under way and an elaborate program has been arranged for additional tests.

Refractories for the Glass Industry.

An investigation is under way and partially completed dealing with the resistance to glass corrosion of various combinations of American clays, involving the use of silicious and aluminous bond clays and of calcines made from the same materials. It has been found that silicious clays as a class resist corrosion better than aluminous materials, but that clays very high in silica are less resistant than those moderately silicious. A combination of clays high in silica with more aluminous ones is therefore most desirable. Dense bodies are more resistant to corrosive action than more porous ones, but there seems to be a certain degree of tolerance with reference to the porosity of silicious clays which is absent in the materials lower in silica. It also appears that the size of the pores is of considerable importance as regards the capillary flow of glass into the structure of the body, a point which requires still further study.

Porcelain.

A study of high fire porcelains has suffered some interruption owing to the transfer of the work from the Pittsburgh branch to the Washington laboratory but has been taken up again vigorously. A series of porcelains containing zirconia and thoria have been made which possess desirable properties particularly excellent resistance to sudden heating and cooling. They are, however, not refractory since even with contents of these oxides up to 50 per cent and with feldspar as low as 8 per cent vitirification took place at temperatures below 1,400° C.

An extensive study is being made of hard fire porcelain glazes, which will supply complete and reliable data concerning the glazes to be employed for the different firing temperatures.

Solubility of Fritts.

A study has been made of the solubility in water of the so-called "fritts" employed in the preparation of glazes for the white-ware pottery industry. The "fritts" are glasses high in boric oxide prepared for the purpose of rendering the boric acid and borax used insoluble, since otherwise a large portion of these constituents would be removed by the water used in grinding. It was found that the thoroughly fused fritts were quite insoluble but that those which were poorly mixed and melted were decidedly soluble. It appears from the results obtained that the use of special melting furnaces for the preparation of the fritt is strongly advisable.

The Effect of Molding Structure Upon the Rate of Vitrification of Porcelains.

Porcelain specimens were made from the same composition but molded by pressing in the plastic state, by casting and by pressing as moist dust under three pressures, 2,000, 4,000, and 6,000 pounds per square inch. Upon firing these specimens in the same kiln under

identical conditions it was found that the dust pressed specimens showed a much slower rate of vitrification than the plastic pressed and cast pieces, but that this rate increased with increase in pressure. Dust pressed porcelains by applying a sufficiently high pressure may therefore be caused to vitrify at a rate approaching that of plastic molded bodies.

Equipment.

The equipment of the new ceramic laboratories at Washington has been completely installed and provision has been made for precision measurements upon the physical properties of clays and ceramic products. The kiln and furnace equipment is very extensive and has been operated sufficiently long to insure its proper functioning. The installation for the making of heavy cast ware is ready for operation.

ENAMELED METALS.

Fish Scaling in Enamels for Sheet Steel.

The jumping off of small particles of enamel which results in the defect known in shop practice as "fish scaling" is probably the most serious defect to which enamels for sheet steel are subjected. It occurs intermittently in practically all the plants manufacturing this class of material in this country and entails losses running into millions of dollars to the manufacturers. At the request of the Metalware Manufacturers Association of America, the Enameled Metal Division of the American Ceramic Society, and of a large number of individual manufacturers, the Bureau is carrying on a comprehensive research in an endeavor to discover the cause or causes of this defect and the methods of controlling and eliminating it. This investigation was begun in July, 1919, and has been conducted energetically ever since. Up to the present time, the investigation has been confined to one-coat gray enamels. The Bureau has made 90 melts of enamel comprised of 21 different compositions. These have been subjected to various treatments in firing and melting and have been applied in various ways to several kinds of steel. In all, over 4,000 sample enameled plates have been made. The work done up to the present time indicates that the primary cause of fish scaling in enamels is higher coefficient of thermal expansion of steel than of the enamels used for coating the steel. Any circumstance which interferes with proper adhesion of the enamel to the steel increases the tendency to fish scaling. Among these may be mentioned the formation of oxide, grease, or other form of dirt on the steel. In one-coat gray enamels, overfiring has a decided tendency to produce fish scaling.

The data obtained in this investigation up to the present time have enabled the Bureau to be of very material assistance to several manufacturers in eliminating this trouble. It seems very probable that the completion of the investigation as now planned will definitely eliminate fish scaling, and likewise settle the interesting question of what is the physical basis of the phenomenon.

The Relation of Composition of Enamel to Solubility in Acids.

For several months the Bureau has had in progress an investigation of the relation of composition of enamel to solubility in strong mineral

acids. The need for this investigation was clearly demonstrated during the war by the difficulty manufacturers of acid-resisting enameled wares experienced in meeting the requirements of chemical manufacturing plants. The manufacturers of enameled kitchen wares are also interested in this problem. Up to the present time, 72 enamel compositions have been melted and tested. While the problem is a large one and the investigational work will necessarily be continued for some time, results so far obtained indicate that some of the commonly accepted conceptions of the relation between composition and acid resistance of enamels are erroneous. The chief of these misconceptions seems to be that oxides which are similar in nature chemically will have similar effects when incorporated in enamel compositions. That this is not always true is shown by the fact that calcium oxide tends to produce enamels with very low resistance to attack of acids while barium oxide produces quite resistant enamels. In connection with the gathering of data on the chief object of this investigation, information is being secured in regard to relations of composition to their fusibility and to the tendency to chip or to craze or crack. As a matter of interest, it may be stated that as a part of this investigation an enamel has been produced which appears to duplicate in composition and working properties the best grade of French acid-resisting enamel.

Study of Opacifying Agents in Enamels.

The Bureau has investigated about ten of the possible substitutes for tin oxide for producing opacity in enamels. Of these it finds that zinc spinel, zirconium dioxide, titanium dioxide, sodium antimonate, and oxide of antimony have promising possibilities as substitutes for tin oxide.

Substitutes for Antimony Oxide in Gray Coat Enamels.

In certain quarters there is objection to the more or less common practice of using a small amount of antimony oxide in one coat enamels on utensils intended for culinary purposes. This objection is based on the rather hypothetical assumption that such enamels may be slightly poisonous. While the Bureau believes this is not the case, at the request of several manufacturers of this type of ware it has undertaken the investigation of possible substitutes for antimony oxides for making such enamels. It has been found that zinc oxide, tin oxide, and zirconium oxide can be used in place of antimony oxide.

Miscellaneous Investigations in Enamels.

The Bureau has conducted various metal investigations in relation to the enameling industry, among which may be mentioned: Methods of cleaning metals for enameling; production of enamels for watch dials; the study of the technique and compositions to be used in enameling silver; the compositions used for enameling cast iron by the dry process and the compositions and technique of enameling sheet steel and cast iron by the wet process.

REFRACTORIES.

Refractory Crucibles.

The division has investigated the making of crucibles from highly refractory oxides and minerals. It has found it possible to make such crucibles without the use of clay or other binder which would tend to reduce the refractoriness of the crucible. One method is to make the crucible with the use of water by tamping the plastic mass inside of a fire-clay mold lined with plaster of Paris. When the mold and crucible are fired to a red heat the plaster of Paris disintegrates and permits the crucible, which is then fairly strong, to be removed from the mold. The crucible is then fired to a high temperature in order to render it sufficiently dense and strong. The other method consists of mixing linseed oil with refractory oxides and shaping the crucible inside of a detachable metal shell. The crucible is then baked in the shell in a core oven in the same way that cores for casting are baked. The shell is then removed and the crucible fired to a high temperature. This firing results in a burning out of the temporary carbonaceous binder and a sintering of the refractory oxides so as to form a dense, strong, and highly refractory crucible. Working in this way crucibles have been produced from titanium dioxide, zirconium dioxide, and carborundum fire sand. This investigation is being continued.

The Heat Conductivity of Metallurgical Refractories.

The refractories section of the division, in cooperation with the heat division of the Bureau, has been conducting an investigation on the heat conductivity of the refractory materials used in metallurgical furnaces. The necessity for this investigation arises from the fact that very little is known quantitatively in regard to the heat conductivity of these materials. The whole question of economic construction and operation of metallurgical furnaces and the possibility of the development of a number of new types of metallurgical furnaces, particularly of electric furnaces, is dependent largely on the extension of our knowledge of the heat conductivity of metallurgical refractories. It is proposed to determine not only the heat conductivity of individual brick made from various refractories, but also of furnace walls made from such brick. To conduct this investigation it has been necessary to develop new types of apparatus and methods of heat measurements. This preliminary work is about completed, and it is hoped that in the near future we will be able to make actual measurements. As a part of this investigation, apparatus and methods that can be used for measuring the heat conductivity of the walls of furnaces in actual operation in metallurgical plants are being developed.

Cooperation with Technical Organizations.

The division has cooperated with many technical organizations, among which may be named the American Ceramic Society, the American Society for Testing Materials, the National Brick Manufacturers' Association, the National Terra Cotta Society, the Sheet Metal Ware Manufacturers' Association, the United States Potters' Association, etc.

Cooperation with Governmental Departments.

Cooperation has been maintained with a number of departments, both as regards information on ceramics, routine tests, and the supply of material. Among these may be mentioned the Navy, the United States Geological Survey, the Panama Canal, the Tariff Commission, the Bureau of Mines, the Washington Navy Yard, the Department of Agriculture, and others. In addition, the division kept in close touch with the activities of the National Research Council.

Assistance Rendered Individual Manufacturers.

The division was visited by many individuals and representatives of corporations with reference to specific problems and the correspondence relating to this work is becoming increasingly voluminous.

GLASS.

Equipment.

The glass plant at the Washington laboratory has been fully equipped and is now in operation. The furnace equipment is complete and permits of the making of all kinds of glass from the different commercial kinds to the highest type of optical glass. The molding apparatus is adequate for conducting all the operations necessary, and skilled glassworkers are available for doing this work properly. Ample provisions have been made for the inspection of optical glass through cooperation with the division on optics and the glass-grinding laboratory of the Bureau.

Colored Glasses.

A large amount of work has been done on colored glasses for a considerable variety of colors and the spectroscopic analysis of the transmitted light. A number of special-colored glasses have been prepared for the Navy and additional ones are being made. A study on the production of selenium red glasses has been published in the Journal of the American Ceramic Society, volume 2, No. 11 (1919). About 50 melts were made in monkey pots.

Optical Glass.

There were made 20 large melts of optical glass, including light crown, medium flint, dense barium crown, light barium crown, and baro-silicate crowns. The new regenerative furnaces have been found to operate very satisfactorily. There were molded from November 1, 1919, to March 1, 1920, 100 six-inch disks, 500 lens blanks, $2\frac{3}{4}$ inches in diameter, of medium flint, and 2,500 blanks of light barium crown. From March 1 to July 1, 1920, there were molded 10,665 lens blanks and slabs, weighing 7,468 pounds.

A large number of lens blanks thus produced were subjected to precision annealing.

Inspection.

The equipment for handling and classifying the glass was greatly improved and precision inspection made a matter of systematized routine. A paper was published in the Transactions of the American Ceramic Society, volume 2, December, 1919, on the subject of "Comparison Tests for Striae in Optical Glass."

Large Lens Blanks.

Pioneer work was done in connection with the molding of large lens blanks, weighing from 38 to 365 pounds, employing clay forms heated in a muffle furnace. This work is being continued and it has been demonstrated that the method employed is satisfactory.

Miscellaneous Work.

A considerable number of inquiries concerning problems in glass technology have been received and answered as fully as possible. In some cases experimental work was necessary in order that the questions might be answered correctly.

Small tubing, one-sixteenth to one half inch, was made up from about 250 pounds of glass for the chemical division of the Bureau.

A considerable number of prism blanks, disks, cylinders, and sheets of optical glass have been made for the use of different divisions.

III. THE OFFICE.

The work of the office includes the general supervision of the clerical work of the Bureau, office management for the central office, including funds and accounts, tests, information, appointment and other matters connected with personnel, the central editing of technical manuscripts, property and stores, mail and files, technical library, dispatch, including all forms of transportation and communication, purchasing, and stenography, typewriting, and duplicating.

During the year special attention was given to perfecting the organization on a peace basis so that essential routine could be carried with a minimum of clerks. The work of the office is in general in better condition than at any previous time in the history of the Bureau, considering the limited force available.

The matter of office space is most serious. In some offices the space per person is less than the minimum standards recognized for office work. In view of the urgent need for laboratory space and the suitability of the south building for that purpose, it is hoped that initial steps may be taken during the year toward the planning of an administration building to house the administrative offices of the Director, the general offices, the library, and the necessary technical conference room, etc.

ACCOUNTS.

Funds and Disbursements.

The regular appropriations of the Bureau amounted to $1,397,260. Additional items, amounting to $495,000, were carried in the first deficiency appropriation act, making a net total of $1,892,260. Reimbursements were received from other departments for certain cooperative researches, although not in the same volume as during the war. The total expenditures during the year amounted to $1,686,345.56. During the current year Congress authorized special transfers of funds from other departments desiring cooperative research for which the Bureau's direct funds are inadequate effective July 1, 1920.

Staff.

The accounting staff was reduced during the year. The loss of four of the senior clerks was a serious handicap, but their successors have done excellent work in the emergency. The test record work and the clerks engaged in test records were transferred to the finance section and the procedure somewhat reorganized. Parts of the work necessarily minimized during the war were brought up to date with the assistance of temporary clerical help. The test work is now proceeding normally.

Appropriation Statements.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1920, the disbursement during the year, the amount of unpaid orders at the close

of the year, and the unexpended balance remaining at the close of business June 30, 1920:

Appropriation.	Amount appropriated.	Disbursements.	Liability.	Balance.
Salaries	$486,760.00	$443,621.86	$19,990.05	$23,148.09
Equipment	[1] 108,033.00	77,873.51	29,655.57	503.92
General expenses	95,000.00	28,354.07	56,689.45	9,956.48
Grounds	7,590.00	6,6[illegible]6.18	8[illegible]8.02	45.80
Testing structural materials	[2] 150,283.29	122,879.59	27,175.78	227.92
Testing machines	[3] 35,263.49	29,804.88	5,452.76	5.85
Metallurgical research	[4] 30,040.63	26,092.74	3,875.00	142.89
Investigation of optical glass	[5] 63,995.34	55,027.79	8,892.44	145.11
Standard materials	5,000.00	3,577.22	1,403.84	18.94
Investigation of textiles, etc	15,000.00	14,609.96	378.39	11.65
Sugar standardization	[6] 21,800.00	17,069.37	4,536.72	193.91
Gauge standardization	[7] 56,276.90	50,675.87	5,304.93	296.10
High temperature investigation	10,000.00	7,206.39	2,762.71	30.90
Testing railroad scales, etc	[8] 43,514.40	34,605.88	8,162.43	746.09
Investigation of fire-resisting properties	25,000.00	21,382.92	3,559.43	57.65
Investigation of railway materials	15,000.00	13,626.59	1,337.42	25.99
Testing miscellaneous materials	30,000.00	27,377.57	2,521.75	101.18
Public-utility standards	[9] 114,159.82	107,089.84	6,954.73	115.25
Radio research	[10] 31,555.94	30,231.34	1,287.29	37.31
Industrial research, 1920	[11] 290.982.39	187,834.20	101,946.12	1,202.07
Sound investigation	[12] 7,237.04	5,378.20	1,760.86	97.98
Investigation of clay products	20,000.00	18,106.19	1,858.15	35.66
Color standardization	10,000.00	8,961.10	999.21	39.69
Physical constants	5,000.00	4,829.00	167.00	4.00
Standardizing mechanical appliances	[13] 50,820.26	36,259.71	14,357.91	202.64
Investigation of mine scales and cars	[14] 15,179.73	14,722.48	403.77	53.48
Industrial safety standards	25,000.00	19,305.84	5,406.50	287.66
Testing Government materials	100,000.00	60,506.51	19,357.37	20,136.12
Standardization of equipment	[15] 52,292.00	19,335.30	14,701.63	18,255.07
Platinum and rare metals	15,000.00	13,385.91	1,598.74	15.35
Retaining wall	20,000.00	15,854.97	4,116.29	18.74
Industrial research, 1919–20	[16] 71,899.23	71,631.42	1.70	266.11
Equipping laboratory, 1919–20	100,000.00	92,551.16	6,827.10	621.74
Total	2,127,593.46	1,686,345.56	364,200.56	77,047.34

[1] Includes reimbursement of $33 from other departments.
[2] Includes reimbursement of $25,283.29 from other departments.
[3] Includes reimbursement of $5,263.49 from other departments.
[4] Includes reimbursement of $5,040.63 from other departments.
[5] Includes reimbursement of $43,995.34 from other departments.
[6] Includes reimbursement of $1,800 from other departments.
[7] Includes reimbursement of $16,276.90 from other departments.
[8] Includes reimbursement of $3,514.40 from other departments.
[9] Includes reimbursement of $29,159.82 from other departments.
[10] Includes reimbursement of $1,555.94 from other departments.
[11] Includes reimbursement of $10,982.39 from other departments.
[12] Includes reimbursement of $2,237.04 from other departments.
[13] Includes reimbursement of $35,820.26 from other departments.
[14] Includes reimbursement of $179.73 from other departments.
[15] Includes reimbursement of $2,292 from other departments.
[16] Includes reimbursement of $21,899.23 from other departments.

The following statement shows the condition of the appropriation for the two preceding fiscal years at the close of business June 30, 1920:

Appropriation.	Amount appropriated.	Disbursements.	Liability.	Balance.
FISCAL YEAR 1918.				
Salaries	$348,900.00	$316,619.03		$32,280.97
Equipment	55,000.00	54,091.89	$803.03	189.08
General expenses	35,000.00	34,009.64	350.08	640.28
Repairs and alterations	5,000.00	4,945.18	46.00	8.82
Grounds	6,000.00	5,946.40		53.60
High-potential investigation	15,000.00	14,533.21	297.94	163.85
Testing structural materials	[1] 210,514.00	186,452.92	14,429.81	9,640.27
Testing machines	30,000.00	29,543.64	38.19	418.17
Investigation of fire-resisting properties	25,000.00	24,881.19		118.81
Public-utility standards	50,000.00	49,952.91	46.73	.36
Investigation of railway materials	15,000.00	14,608.99	28.50	362.51

[1] Includes reimbursement for $60,514.

Appropriation.	Amount appropriated.	Disbursements.	Liability.	Balance.
FISCAL YEAR 1918—continued.				
Testing miscellaneous materials	$20,000 00	$19,973.28	$26.55	$20 17
Radio research	10,000 00	9,969.24	.....	30 76
Color standardization	10,000 00	9,666.58	126.90	206.52
Investigation of clay products	10,000 00	9,994.53	.....	5.47
Physical constants	5,000 00	4,994 31	.....	5.69
Standardizing mechanical appliances	10,000 00	9,567.18	.....	432.82
Investigation of optical glass	10,000 00	9,910.78	65.75	23.47
Testing railroad scales	40,000 00	39,712 03	107.27	180 70
Additional land	25,000 00	.....	.....	25,000.00
Military research, 1917–18	[1] 487,245.36	467,902 38	4,141.49	15,201.49
Gauge standardization, 1917–18	[2] 226,972 47	223,935.10	2,256.67	780 70
Repairs, power plant	12,000 00	11,744.57	.....	255.43
National security and defense.				
Production of optical glass	[3] 112,762.00	108,293.55	1,364.31	3,104.14
New building	250,000.00	249,947.53	.....	52.47
Metallurgical work	100,000 00	99,284.82	292 07	423.11
Production of fabrics	35,000.00	34,298.65	378.75	322.60
Industrial laboratory	893,500.00	883,840 80	9,186.97	472.23
Roberts's coke oven	45,000.00	31,514.70	11,559.70	1,925.60
Thermite investigation	700.00	655.20	10 90	33.90
Total	3,098,593 83	2,960,685.23	45,554.61	92,353.99
FISCAL YEAR 1919.				
Salaries	432,360.00	374,832.59	1,168.03	56,359.38
Equipment	[4] 81,200.00	72,776.48	7,602.62	821.50
General expenses	[5] 50,100.76	45,796.20	4,220.58	83.98
Grounds	7,500.00	7,285.82	.....	214.18
High-potential investigation	15,000.00	14,619.24	239.16	81.60
Testing structural materials	[6] 233,628.29	224,342.63	2,422.02	6,863.64
Testing machines	30,000.00	29,200.58	739.87	59.55
Investigation of fire-resisting properties	25,000.00	24,563.71	239.73	196.56
Public utility standards	[7] 55,000.00	53,080.02	1,882.51	37.47
Investigation of railway materials	15,000.00	14,858.64	12.54	128.82
Testing miscellaneous materials	30,000.00	29,672.99	122.70	204.31
Radio research	20,000.00	19,838.41	.....	161.59
Color standardization	10,000.00	9,786.45	172.98	40.57
Investigation of clay products	20,000.00	19,766.10	44.68	189.22
Determining physical constants	5,000.00	4,972.18	26.99	.83
Standardizing mechanical appliances	10,000.00	9,861.79	14.98	123.23
Investigation of optical glass	[8] 84,388.75	82,053.63	1,731.03	604.09
Standard materials	4,000.00	3,833.24	96.60	70.16
Investigation of textiles, etc	10,000.00	9,528.41	360.50	111.09
Sugar technology standards	[9] 21,350.00	20,077.31	1,187.23	85.46
Gauge standardization	[10] 433,000.00	422,763.48	7,369.88	2,926.64
Renewal of storage batteries	20,000.00	8,985.68	10,258.29	756.03
Military research, 1918–19	[11] 633,495.57	592,979.94	38,506.33	2,009.30
Investigation of mine scales, and cars, 1918–19	15,000.00	14,677.73	103.26	219.01
Investigation of public-utility companies, 1918–19	[12] 53,522.52	51,530.30	1,904.71	27.51
Testing railroad scales, etc	[13] 41,104.70	39,074.89	752.03	1,277.78
National security and defense.				
Military researches	100,000.00	95,283.61	2,888.78	1,827.61
Robert's coke oven	40,000.00	29,179.85	10,728.12	92.03
Thermite investigation	4,300.00	3,906.84	344.57	48.59
Altitude laboratory	60,000.00	59,897.19	.....	102.81
Power-plant equipment (industrial laboratory)	31,500.00	31,461.61	.....	38.99
Completing laboratories	235,000.00	231,870.41	1,631.24	1,498.35
Armament of fortifications, commerce transfer	[14] 198,907.20	139,510.77	6,883.01	52,513.42
Aviation, Navy, commerce transfer	5,000.00	4,998.28	1.30	.42
Total	3,036,357.79	2,796,806.40	103,775.67	129,775.72

[1] Includes reimbursement of $237,245.36 from other departments.
[2] Includes reimbursement of $1,972.47 from other departments.
[3] Includes reimbursement of $37,762 from other departments.
[4] Includes reimbursement of $200 from other departments.
[5] Includes reimbursement of $100.76 from other departments.
[6] Includes reimbursement of $108,628.29 from other departments.
[7] Includes reimbursement of $5,000 from other departments.
[8] Includes reimbursement of $84,388.75 from other departments.
[9] Includes reimbursement of $1,350 from other departments.
[10] Includes allotment of $233,000 from War Department.
[11] Includes reimbursement of $233,495.57 from other departments.
[12] Includes reimbursement of $3,522.52 from other departments.
[13] Includes reimbursement of $1,104.70 from other departments.
[14] Includes reimbursement of $98,907.20 from other departments.

Summary of Tests.

The Bureau's work includes, among other things, a large amount of testing standards, measuring instruments, and materials. Incident thereto, much of the testing involves primarily investigation of the scientific principles underlying the tests, the studying of existing methods, and the development of new standard tests of determinate accuracy. For each test a reasonable fee is charged, except when made for the National or State Governments. The number of tests completed during the year, together with their value, is shown in the following table:

NUMBER AND VALUE OF TESTS COMPLETED,[1] FISCAL YEAR ENDING JUNE 30, 1920.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length:						
Tapes	207	$474.70	94	$247.45	301	$722.15
Other length tests	1,806	1,881.65	1,191	1,851.48	2,997	3,733.13
Mass:						
Weights	1,164	516.10	3,057	1,333.50	4,221	1,849.60
Scales and balances	1,032	33,713.50	3	6.00	1,035	33,719.50
Capacity	742	617.75	5,581	3,120.55	6,326	3,738.30
Hydrometry	145	153.60	377	695.25	522	848.85
Time	5,509	6,713.50	49	142.00	5,558	6,855.50
Electrical tests	665	2,025.05	567	2,896.28	1,232	4,921.33
Photometry [2]	1,919	6,595.00	103	280.50	2,022	6,875.50
Radioactivity	13	5.00	1,102	6,667.10	1,115	6,672.10
Temperature:						
Clinical thermometers	22,848	2,048.04	1,221	147.92	24,069	2,195.96
Other thermometers and miscellaneous	3,631	1,769.21	3,322	4,859.87	6,956	6,629.08
Optical tests:						
Sugar polarimetry	1,522	1,522.06	11	26.25	1,533	1,548.25
Other optical tests	2,030	2,260.00	11,914	4,182.35	13,944	6,442.35
Chemical analyses:						
Structural materials	1,798	17,698.50	.....	.....	1,798	17,698.50
Other materials	7,515	114,723.00	33	167.00	7,548	114,890.00
Standard samples	607	1,177.80	5,037	9,747.95	5,644	10,925.75
Mechanical instruments and appliances	376	2,010.50	72	400.00	448	2,410.50
Aeronautical instrument tests	134	887.50	5	71.00	139	958.50
Physical tests of materials:						
Cement	8,410	66,022.50	2	6.00	8,412	66,028.50
Other structural materials	2,229	5,030.10	125	606.50	2,354	5,636.60
Miscellaneous materials, including paper, textiles, rubber, leather, etc.	7,156	24,129.75	357	901.00	7,513	25,330.75
Metallurgical tests	810	2,227.00	62	333.75	872	2,560.75
Miscellaneous	127	1,152.50	213	760.40	340	1,913.10
Total	72,398	295,651.25	34,501	39,450.30	106,899	335,104.55

[1] The tests reported in this table include only the tests for which all technical procedure was entirely completed during the year 1919-20.

[2] In addition the Bureau inspected 1,320,479 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $3,514.01.

PERSONNEL.

Scope.

The personnel office handles the business connected with appointment, transfers, separations, and similar matters, and also the preparation and maintenance of Bureau directories, first-aid and injury reports required by the United States Employees' Compensation Commission, and special records, statistics, and reports required by the administration of the Bureau, the department, and the Civil Service Commission.

Personnel of Bureau.

During the year the Bureau's staff comprised 381 statutory employees and about 600 engaged in research and investigations especially authorized by Congress. The statutory positions included 211 scientific positions, 55 office assistants, 76 engaged in the operation of the plant, and 40 in the construction. The personnel at present consists of 981 regularly appointed employees, as compared with 1,080 at the close of the fiscal year ended June 30, 1919. The above figures show that the force has been reduced by approximately 100 employees during the past fiscal year. There were 2,408 personnel changes during the year. This total includes 850 separations from the Bureau, of which 397 were resignations, 573 promotions, and 836 appointments. The turnover in the permanent force of the Bureau was therefore about 40 per cent, but if all separations and reappointments be included this figure would be approximately 100 per cent. A detailed statement of the personnel changes is given in the following table:

PERSONNEL CHANGES, 1918–19.

Nature of action.	Appointments.		Separations.	
Competitive	281		367	
Excepted	3		.....	
Unclassified	35		30	
Total permanent		319		397
Temporary	517		453	
Total appointments and separations	836		850	

Eligibles.

The status of civil-service eligibles is practically the same as reported last year. Owing to the continued shortage of trained technical and scientific men and the unusual demand for such assistants in the industries, the Civil Service Commission can furnish directly less than 10 per cent of the eligibles required for appointment to the technical positions in the Bureau. It is still necessary for the Bureau to advertise and find applicants outside of the civil-service registers and request them to take the examinations. This condition, of course, was the cause of the large number of temporary appointments during the year, since it is usually necessary to make temporary appointment pending the completion of the necessary papers for permanent appointment.

Personnel Records.

Graphic records are kept of the staff and of the distribution of salaries and positions by divisions and months. These records are very useful in comparing the relative status of the divisions with respect to personnel and expenditures for services. A careful record is kept of the educational status of the minor assistants, with a view not only of advising them and encouraging them to secure advanced schooling in their special subjects, but also to serve as a guide in

matters of training, promotion, and transfer. To facilitate the transaction of Bureau business a carefully prepared personnel directory is mimeographed quarterly with supplements monthly.

Status of Work.

Attention is called to the large number of special administrative reports which are required, such as the information called for by the Reclassification Commission and other agencies. The reduction in force leaves the staff at about a normal number to handle efficiently the lines of personnel work proper. This office has in preparation written specifications covering all classes of positions in the Bureau.

PUBLICATIONS.

New Publications.

During the fiscal year just closed the Bureau has issued 106 new publications, 5 revised editions, 2 supplements to the Bureau's list of publications, and 21 reprints—134 publications in all. The 106 new publications comprise 50 scientific papers, giving results of new scientific researches; 37 technologic papers, giving results of new investigations in the fields of engineering and general technology; 16 circulars, containing important compiled technical information in the Bureau's field and useful to the industries, and especially to scientific and technical laboratories; and 3 miscellaneous publications.

The two supplements mentioned contain a list of Bureau publications issued since the 1919 edition of Circular 24, entitled "Publications of the Bureau of Standards." The supplements also give a list of the publications no longer available for free distribution by the Bureau and contain a classified list of the libraries throughout the country where the Bureau's publications may be consulted.

Announcements and Distribution.

In view of the many urgent requests received by the Bureau for more effective means of keeping the public informed of the results of the Bureau's work, special attention is being given to announcing its new publications. Such announcement is made in several ways: (*a*) Through a monthly list issued by the superintendent of documents, of which a large edition is circulated; (*b*) through the monthly list of publications of the Department of Commerce, of which more than 10,000 copies are distributed to journals, industrial concerns, and libraries; (*c*) through technical abstracts of each new publication sent to the technical press; (*d*) through the Bureau's monthly issues of the Technical News Bulletin; and (*e*) in Circular 24, the classified, descriptive list of the Bureau's publications.

In order to more effectively reach the special industrial and scientific interests directly concerned with the Bureau's work, it is now planned to issue card announcements to those who actually need the publication, and to keep specialists posted on the technical work of the Bureau.

The announcement of new publications is systematically handled, notices being sent to technical journals, libraries, technical institutions, and carefully selected lists of specialists concerned with the subjects treated.

The publications of the year include the following:

Scientific Papers.

The Effect of Rate of Temperature Change on the Transformations in an Alloy Steel.

Constitution and Metallography of Aluminum and its Light Alloys with Copper and with Magnesium.

Some Optical and Photoelectric Properties of Molybdenite.

Standardization of the Sulphur Boiling Point.

A Standardized Method for the Determination of Solidification Points, Especially of Napthalene and Paraffin.

Airplane Antenna Constants.

Reflecting Power of Stellite and Lacquered Silver.

Location of Flaws in Rifle-Barrel Steel by Magnetic Analysis.

Spectral Photoelectric Sensitivity of Silver Sulphide and Several Other Substances.

Measurements of Wave Lengths in the Spectra of Krypton and Xenon.

Oxygen Content by the Ledebur Method of Acid Bessemer Steels Deoxidized in Various Ways.

Heat Treatment of Duralumin.

Use of a Modified Rosenhain Furnace for Thermal Analysis.

Photoelectric Spectrophotometry by the Null Method.

Equilibrium Conditions in the System Carbon, Iron Oxide, and Hydrogen in Relation to the Ledebur Method for Determining Oxygen in Steel.

Dependence of the Input Impedance of a Three-Electrode Vacuum Tube Upon the Load in the Plate Circuit.

Thermal Expansion of Insulating Materials.

Variation in Direction of Propagation of Long Electromagnetic Waves.

Principles of Radio Transmission and Reception with Antenna and Coil Aerials.

Determination of the Output Characteristics of Electron Tube Generators.

Microstructure of Iron and Mild Steel at High Temperatures.

Constants of Radiation of a Uniformly Heated Inclosure.

Concerning the Annealing and Characteristics of Glass.

Efflux of Gases Through Small Orifices.

Methods for Computing and Intercomparing Radiation Data.

Magnetic Testing of Straight Rods in Intense Fields.

Distribution of Energy in the Spectrum of an Acetylene Flame.

Preparation and Reflective Properties of Some Alloys of Aluminum with Magnesium and with Zinc.

Relation of Voltage of Dry Cells to Hydrogen-Ion Concentration.

A New Interferential Dilatometer.

Contrast Sensibility of the Eye.

Turbidity Standard of Water Analysis.

Ionization and Resonance Potentials for Electrons in Vapors of Lead and Calcium.

Vapor Pressure of Ammonia.

A New Form of Vibration Galvanometer.

A New Cadmium Vapor Arc Lamp.

Wave Lengths Longer Than 5.500 A in the Arc Spectra of Seven Elements.

Characteristics of Striae in Optical Glass.

An Integration Method of Deriving the Alternating-Current Resistance and Inductance of Conductors.

The Double-Polarization Method for Estimation of Sucrose and the Evaluation of the Clerget Divisor.

Critical Ranges of Some Commercial Nickel Steels.

The Intercrystalline Brittleness of Lead.

A New Spectropyrheliometer and Measurements of the Component Radiations from the Sun and from a Quartz Mercury Vapor Lamp.

Reflecting Power of Monel Metal, Stellite, and Zinc.

The Spectro-Photoelectric Sensitivity of Thalofide.

An Electron Tube Transmitter of Completely Modulated Waves.

Notes on the Testing of Magnetic Compasses.

Measurement of Hysteresis Values from High Magnetizing Forces.

Variation of Residual Induction and Coercive Force with Magnetizing Force.

A New Microphotometer for Photographic Densities.

Technologic Papers.

Leakage Resistance of Street-Railway Roadbeds and Its Relation to Electrolysis of Underground Structures.

Notes on the Graphitization of White Cast Iron Upon Annealing

A Comparison of the Heat-Insulating Properties of Some of the Materials Used in Fire-Resistive Construction.

Application of the Interferometer to Gas Analysis.

Mechanical Properties and Resistance to Corrosion of Rolled Light Alloys of Aluminum and Magnesium with Copper, with Nickel, and with Manganese.

Tests of Flexible Gas Tubing.

Experimental-Retort Tests of Orient Coal.

Behavior of Wrought Manganese Bronze Exposed to Corrosion While Under Tensile Stress.

The Determination of Free Carbon in Rubber Goods.

Coking of Illinois Coal in Koppers Type Oven.

Effects of Glucose and Salts on the Wearing Quality of Sole Leather.

Some Tests of Light Aluminum Casting Alloys—The Effect of Heat Treatment.

Constant-Temperature Still Head for Light-Oil Fractionation.

An Electrolytic Resistance Method for Determining Carbon in Steel.

Materials and Methods Used in the Manufacture of Enameled Cast-Iron Wares.

A Study of the Deterioration of Nickel Spark-Plug Electrodes in Service.

The Properties of American Bond Clays and Their Use in Graphite Crucibles and Glass Pots.

Direct Determination of India Rubber by the Nitrosite Method.

The Cadmium Electrode for Storage Battery Testing.

An Apparatus for Measuring the relative Wear of Sole Leathers, and the Results Obtained with Leather from the Different Parts of a Hide.

The Ultra-Violet and Visible Transmission of Various Colored Glasses.

Estimation of Nitrates and Nitrites in Battery Acid.

Physical Tests of Motor-Truck Wheels.

Load Strain-Gage Test of 150-Ton Floating Crane for the Bureau of Yards and Docks, U. S. Navy Department.

Investigation of the Compressive Strength of Spruce Struts of Rectangular Cross Section and the Derivation of Formulas Suitable for Use in Airplane Design.

Area Measurement of Leather.

Determination of Cellulose in Rubber Goods.

Cements for Spark Plug Electrodes.

Metallographic Features Revealed by the Deep Etching of Steel.

An Investigation of the Physical Properties of Dental Materials.

A Peculiar Type of Intercrystalline Brittleness of Copper.

Porosity and Volume Changes of Clay Fire Bricks at Furnace Temperatures.

Effects of Oils, Greases, and Degree of Tannage on the Physical Properties of Russet Harness Leather.

A Picnometer for the Determinaion of Density of Molasses.

Extraction of Rubber Goods.

Stresses Caused by Cold-Rolling.

The Saybolt Viscosity of Blends.

Circulars.

Protective Metallic Coatings for the Rustproofing of Iron and Steel.

Bibliography of Scientific Literature Relating to Helium.

Specifications for the Manufacture and Installation of Railroad Track Scales.

Recommended Specifications for Basic Carbonate White Lead, Dry and Paste.

Recommended Specification for Basic Sulphate White Lead, Dry and Paste.

Recommended Specifications for Turpentine.

Recommended Specifications for Zinc Oxide, Dry and Paste.

Recommended Specifications for Leaded Zinc Oxide, Dry and Paste.

Recommended Specifications for White Paint and Tinted Paints Made on a White Base—Semipaste and Ready Mixed.

Recommended Specifications for Red Lead, Dry and Paste.

Recommended Specification for Ocher, Dry and Paste.

Operation and Care of Vehicle-Type Batteries.

Recommended Specification for Iron-Oxide and Iron-Hydroxide Paints.

Recommended Specification for Black Paint, Semipaste and Ready-mixed.

Inks—Their Composition, Manufacture, and Methods of Testing.
Recommended Specifications for Quicklime and Hydrated Lime for Use in the Cooking of Rags for the Manufacture of Paper.

Miscellaneous.

Household Weights and Measures.
Annual Report of the Director of the Bureau of Standards for 1919.
Report of the Twelfth Annual Conference on Weights and Measures of the United States.

MAIL AND FILES.

Volume of Mail.

The volume of the Bureau's mail is steadily increasing. Approximately 150,000 pieces were handled during the past year in the file room proper, apart from other mails such as technical journals, catalogues, and documents, which would amount to as much additional. In addition, through the dispatch room were transmitted 75,000 communications for the various divisions and sections.

Indexing and Filing.

The more important mail is specially recorded alphabetically by writer, numerically by subject, and also by date. Of this class of mail there were about 50,000 pieces. The perfecting of the case system of filing involved much extra work in the file room, and the reduction in force increased the difficulty, but by careful planning and efficient service the staff has brought the files into better condition than at any time in recent years. Special sorting units, designed and constructed at the Bureau, facilitated the handling of communications. A system of compression guides installed in all filing units of the central files has materially lightened the fatigue and labor involved in inserting and removing material from the files.

Loans of Correspondence.

A more systematic method of making and charging loans has been developed, so that record of the location of all letters is now available.

PROPERTY AND STORES.

The office of property and stores administers all matters involved in the accession, distribution, accountability, and records of property, both equipment and supplies, and also the work involved in receipt and shipment of instruments and materials of all kinds, including the packing and shipping of all instruments tested by the Bureau. These functions include the supervision of all Bureau storerooms, the shipping room, and delivery trucking. The work is now well organized and proceeding efficiently.

During the year 64,800 items of property and supplies were received and inspected by the staff in charge of property and stores. The inventoried items of equipment included 15,000 pieces of apparatus or other equipment. Supplies were dispensed through the storeroom to a value of approximately $62,000.

Approximately 12 tons of instruments and other technical materials passed through the shipping room per week, and 8 tons additional transportation were required outside of the shipping room. Through the cooperation of the freight and express officers, the

Bureau has arranged to eliminate storage and demurrage charges heretofore unavoidably incurred owing to transportation conditions in Washington and the trucking facilities of the Bureau.

LIBRARY.

The Bureau's scientific and technical reference library now contains 19,479 accessioned volumes chiefly in physics, engineering, and chemistry. In addition there are currently received at the library 468 technical and scientific periodical publications.

There were accessioned during the past year 1,740 volumes, including 880 volumes of periodicals. The labor incident to ordering, accessioning, cataloguing, binding, labeling, and circulating these books is considerable.

The cooperation with other libraries in the city has been continued. Books are loaned to other libraries, and in turn the other libraries, especially the Library of Congress, have extended like courtesy to the Bureau. The broad field of the Bureau's work has made this arrangement a very essential part of the library system.

PURCHASE.

Bids and Orders.

The Bureau orders issued during the year numbered over 8,000 and included 1,500 exigency orders, 90 special orders through the Division of Supplies, and 6,500 regular orders. The purchase office handled 1,600 proposals covering the needs of practically every part of the Bureau's work, following the essential routine required by the Government. A systematic record of bids and purchases is maintained to aid the Bureau's staff and facilitate the purchase work. The section prepares formal contracts for the larger purchases and enterprises. The routine connected with travel authorizations involving travel expenses also devolves on the purchase section. Nine hundred travel authorizations and the records incident thereto were handled during the year. The newly systematized catalogue library has effectively aided the Bureau's staff in finding sources of needed materials.

Organization and Records.

After a systematic study the purchase section has a very effective organization and efficient system of routine and records for handling the purchases of the Bureau. The analysis and charting of the system was completed during the year. The records are in excellent condition. Under post-war conditions some sacrifice must be made, and the reduction in force necessitated curtailing useful parts of the work, which reduces somewhat the efficiency of the purchase system as planned.

INFORMATION.

Technical Documents.

The information section maintains a reference file of general technical documents and these are listed and the various scientfic divisions notified each week of new accessions. The documents may be withdrawn for consultation by those concerned. This section has thus served as a clearing house for technical information other than that given in the current scientific journals and new books received at the Bureau's library.

Special Reports.

Statements are prepared, usually at the request of other Government departments or bureaus or industrial organizations, giving information concerning certain specific phases of the Bureau's work. During the year such technical reports were prepared on the following subjects: Development of optical glass at the Bureau of Standards; description of the general work of the Bureau for the use of a publicity work; the engineering work of the National Bureau of Standards; the work of the Bureau of Standards 1912–1920; aeronautical work of the Bureau of Standards; the present significance of the war work of the Bureau of Standards; the work of the Bureau of Standards in the development of new and substitute materials during the war; the facilities of the National Bureau of Standards as regards the testing of ordnance equipment; and a brief description of the Bureau of Standards with photographic illustrations.

Once each month there is issued for publication in a scientific journal a brief statement of the work current during the previous month. The section prepares a monthly "Technical News Bulletin" containing a summary of the more important work accomplished in the various scientific divisions. This bulletin has been in greater demand among industrial concerns than ever before and has proved very useful in keeping manufacturers in touch with new technical information in the various fields covered by the Bureau.

Distribution of Documents and Directing of Inquiries.

Incoming inquiries from the industries and others are routed to the members of the Bureau's staff best qualified to answer the questions. The Technical News Bulletin above mentioned, supplied to a mailing list of more than 400, gives a large amount of information which would otherwise involve considerable correspondence. This section also refers incoming mail of a scientific character to the various divisions of the Bureau.

Analyses and Compilations.

This section compiles special information on particular subjects based on circulars and documents received by the Bureau. A card index permits ready reference of mail relating to abstracts from the journals of the various associations and similar material to the parties most concerned with the subject.

A progress of work record is maintained of important military and industrial tests. This permits a systematic follow-up throughout the Bureau for such tests.

Visitors.

Considerable time is devoted to interviews with persons visiting the Bureau. In the case of visitors interested in some particular technical subject, the information section endeavors to put them in touch with those best qualified to answer their inquiries. Very often visitors learn in this way of facilities which the Bureau possesses and which can be used to help them in their work. The value of the personal contact thus established is considerable in making the results of the Bureau's work available for use by the general public.

IV. ENGINEERING AND CONSTRUCTION.

POWER PLANT, BUILDINGS AND GROUNDS, AND TRANSPORTATION.

This division is concerned with the operation of the power plant, the maintenance of the transportation service, the installation and repair of electrical equipment and plumbing, and with the care of the buildings and grounds.

OPERATION AND MAINTENANCE OF MECHANICAL PLANT.

Operation of Plant.

The mechanical plant comprises the heating, generating, and refrigeration equipment; compressed air; vacuum and high pressure water services; and storage batteries, stationary and portable. Very few additions were made to the equipment, which is consequently seriously overloaded at times. A 125-kilovolt-ampere frequency changer was installed for obtaining 3-phase 60-cycle power from the 3-phase 25-cycle main supply of the plant. This machine is required essentially for the industrial building, in which are installed a large number of 3-phase 60 cycle motors. Fifty kilovolt-ampere were added to the transformer capacity of the 60-cycle commercial service, bringing the present capacity up to 150 kilovolt-ampere in this service. Several power plant appliances were installed for observing plant performance and enabled a much more economical operation of the boilers than had ever been obtained before. The boiler plant at the kiln building was put into full operation and gave entire satisfaction. Motor drives were installed for the chemistry building plenum fans and are giving far better service than the old steam engines which they replace.

Need of New Power Plant.

It can not be too strongly emphasized that the present plant is entirely inadequate for the needs of the Bureau. As stated in the previous annual report, its expansion under present conditions is quite impractical, as is also a complete remodeling of the whole plant. A conservative new central plant adequate for immediate requirements and capable of expansion to accomodate future growth of the Bureau, should be constructed at once. The indefinite deferment of the construction of the new plant is unwise, in view of the higher operating costs, poorer efficiency and service, and numerous operating difficulties that attend the present plant. In spite of present high prices for materials and labor, the construction of a new plant at once would unquestionably prove an ultimate saving, when all of the foregoing points are taken into consideration.

TRANSPORTATION.

With the aid of some trucks supplied to the Bureau by the War Department, adequate transportation service has been furnished dur-

ing the year. New administrative policies were put into effect during the year and the resulting improvement in service and efficiency has been very gratifying. There is still room for improvement along this line, but indications are promising for further betterment.

CONSTRUCTION AND REPAIR.

Electrical.

The installation, extension, and repair of all electrical wiring, switchboards, motors, and similar equipment for the various laboratories as well as for the mechanical plant are handled by this section. The equipping of the various laboratories in the industrial building and the new dynamometer building required a fairly large number of mechanics throughout the year. The construction work at the industrial building was most extensive, including the installation of the permanent alternating current and direct current distribution feeders and risers, numerous motors, control panels, and various types of electrical equipment in the different laboratories. Some temporary wiring was installed, but most of the foregoing items were of permanent construction. In the dynamometer building the wiring, switchboards, etc., were completed for a number of dynamometers and for auxiliary equipment for the altitude laboratories. Numerous other new installations were made throughout the Bureau. Construction work for the mechanical plant included the installation of the motors for the plenum fans in the chemistry building, resistance flue gas thermometers for five boilers in the north building, frequency changer in engine room and feed lines to industrial building. Owing to the pressure of so much new construction work, chiefly to provide for the industrial building, maintenance work was not kept up as well as would otherwise have been the case, although progress was made in bringing such work up to date toward the end of the year. The maintenance of elevators, lighting circuits, switchboards, and motors for various purposes in the mechanical plant will probably receive more attention and inspection during the coming year, since the new construction work has decreased in amount very decidedly.

Plumbing.

What has been said in regard to electrical installation and maintenance work applies very largely to the plumbing work also. The most extensive construction work was carried on in the industrial building, where the headers and risers for distribution to the laboratories of water, steam, gas, and air were installed, and the distribution piping practically completed in all the laboratories. The air and gas piping for all the kilns and furnaces in the kiln house was completed, and a large amount of apparatus and equipment was put into operation throughout the industrial building. The remaining construction work, while not so extensive, was made up of a large number of small jobs fairly well distributed. Extensive repairs were made to plant equipment such as pipe lines, valves, traps, etc., and maintenance work as a whole was well taken care of. There is a great deal of plumbing and electrical construction work still on hand, but its completion is not as urgent as was that of similar work during the past year.

Minor Construction.

This work includes small jobs of miscellaneous character that are not given out on contract, such as the building of temporary structures, construction and repair of roads, and repairs and alterations to buildings. This work is very closely allied with the care of buildings and grounds. Foundations were constructed for the erection of two steel wireless station towers; roads were constructed east of the industrial building and at the wind tunnel and radio buildings; an incinerator was built and has been in continual use; building repairs of every description were made. At the beginning of the year a large amount of construction work still remained incomplete in the industrial building. Practically all such work has now been completed.

BUILDINGS AND GROUNDS.

Janitors and Laborers.

The work of this section is of more or less routine nature and comprises the cleaning of the many offices and laboratories of the Bureau and the maintaining of sanitary conditions throughout. Although five additional janitor positions were authorized for the year, the care of the industrial and dynamometer buildings was added, so that there was still an insufficient number of men to properly care for all the work. The scarcity of help necessitated rigid supervision of all workmen, and very good results were obtained with the help available. Such results were due mainly to the systematic manner of handling the work, of granting leave, and of requiring strict accountability for all time the men were at work.

Watchmen.

The duties of the watchmen consist in making inspections of the buildings to prevent fire, theft, and damage by weather, etc., to the property of the Bureau. They are also required to report anything pertaining to the various functions of this division that are in need of attention, such as repair of locks, leaks, and the like. Waste of power, gas, water, etc., is also minimized at night by requiring watchmen to turn off all appliances using such facilities that are unintentionally left in operation in the laboratories. Owing to the addition of two new buildings in the past two years, the watchmen's force is no longer adequate for the safeguarding of the Bureau's property.

Grounds.

No extensive improvements were taken up due to the insufficiency of funds for such purposes. Some additional temporary roads were built, and others kept in repair. Routine work was very well handled and considerable progress made on cleaning up portions of the grounds left in bad condition by building operations. A plan is being worked out for permanent road construction and general improvement of the landscape. The acquisition of adjoining land to the north and south will greatly improve the Bureau's site.

V. GENERAL RECOMMENDATIONS.

Salaries.

Attention is again called to the necessity for adjusting the salaries of the scientific and technical experts of the Bureau to compare more favorably with those paid by scientific and industrial laboratories, as well as educational institutions. It is to be regretted that this adjustment could not have been made during the year, since all scientific work of the Government has suffered to a greater or less extent. The demand for men capable of undertaking scientific and technical investigations is far greater than the supply; this, coupled with the present rate of compensation in Government work, has lowered the standard of workers available and greatly impaired the quality as well as the quantity of work. The number of changes in personnel during the year has been many times that under normal conditions. Here, again, the result has been decreased efficiency and a reduction of output. It is realized that conditions throughout the year were not such as to permit of a general reclassification of positions and adjustment of salaries, but it is urgently hoped that it can be done during the coming year. Many of the minor employees of the Bureau are paid less than a living wage, and the salaries of mechanicians and mechanics of all kinds are in many cases less than the salaries paid for similar services in other bureaus of the Government, and in practically all cases much less than the compensation paid for the same class of service in the industries.

The nature of the Bureau's work is such that it should command at all times a certain proportion of the best scientific ability, the most skilled workmen, and the most accurate clerical service.

Power Plant.

The power plant of the Bureau of Standards is entirely inadequate. It consists of the original plant, designed to supply two buildings, and two temporary boiler plants added later. These installations should be combined in one plant capable of heating the various buildings. It should also provide the various electrical currents for power and experimental purposes, as well as the refrigeration, compressed air, vacuum, and other utilities required in scientific work. The need for this plant has existed for the past three or four years, but it was not possible to enlarge the original plant during that period except by the addition of the temporary heating plants referred to. During the present year the inadequacy of power generated at the Bureau, as well as that provided by the public service, has been such as to cause constant interruption of work, loss of time, and interference with experimental work. In several cases valuable data and experimental work have been made useless by stoppage of the current.

Specification, Inspection, and Testing of Materials Purchased by the Government.

The Government method of purchasing materials and supplies of all kinds by means of competitive bids often leads to injustice to the manufacturer and loss of money to the Government unless based upon correct specifications, methods of testing, and the testing of deliveries. The bureaus of the Government recognize this and are utilizing the Bureau of Standards as a testing laboratory to a far greater extent than ever before, both in the preparation of standards of quality and the testing of samples delivered. However, the demand for the work has grown to such an extent that the Bureau has only been able to comply with a small part of the requests made for such services. There is no question as to the necessity for the work, or as to the economy of a central testing plant, but if the facilities of the Bureau are not soon made more adequate for this work, the bureaus of the Government will be compelled to set up their own testing laboratories.

Cooperation with the Industries in Investigational Work.

The necessity for scientific research in connection with the industries was never as great as at present. New processes are being developed and old ones improved, domestic materials are being substituted for imported ones, and the factors upon which the quality or usefulness of a material or device depend are being studied as never before. In all of this, the work of the Bureau is more or less vitally involved, first from the standpoint of the standards and methods of measurement, and second from the standpoint of the efficiency gained by the working out of the fundamental problems at a central laboratory, problems, the solution of which results in data required by an industry as a whole.

The direct assistance given by the Bureau to the industries along these lines would alone warrant its maintenance many times over. During the war the Bureau cooperated with the military departments in researches of many kinds. During the past year a special fund was provided for such cooperation with the industries and an analysis of the results will leave no question as to the usefulness of or necessity for such work by the Bureau. The funds available for this purpose during the coming year are entirely inadequate and it is earnestly recommended that in submitting the estimates for the next year a suitable fund be requested for cooperation with the industries in scientific research.

Buildings and Grounds.

The provision by Congress for the purchase of the small tracts of land between the Bureau's present site and the streets to the north and south, rounds out the Bureau's site with the exception of the land between the present site and Connecticut Avenue on the east. The latter should be secured before it is built upon.

A more adequate fund should be provided for the care of the buildings and grounds. The former are not sufficiently well kept with the force available. The addition to the site will require additional grading, cleaning up, and maintenance.

Test-Car Depot.

Estimates will be submitted for a small building in which to house and care for the Bureau's test cars and master track scale. This important service can be made more efficient by providing a small depot centrally located, for although every effort has been made to handle this from Washington, experience has shown that such a small substation is necessary.

Respectfully,

S. W. STRATTON,
Director.

To Hon. J. W. ALEXANDER,
Secretary of Commerce.